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DESIGN OF AN OPTIMUM CONTAINER FOR PETROLEUM PRODUCTS FOR FIELD USE BY THE ARMY

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ABSTRACT

The purpose of the research was to determine the optimum size and shape for the design of a container for petroleum products when being used by the Army under field conditions similar to those encountered in the more forward areas of a combat zone. Requirements for the selection of the material from which the container is to be made were also included in the problem for consideration as to their effect on the optimum size and shape. The relative importance of these requirements was determined, and a general set of specifications was developed.

The requirements were formulated by the writer after a study of the literature concerning present methods of handling the supply of petroleum products by the Army and by industry. Personal interviews with persons directly connected with the petroleum supply problem in the Army were also utilized. The requirements were then classified in two categories: those affecting the determination of the optimum size and shape, and those affecting the determination of the optimum material. A questionnaire was designed to include the sets of requirements thus derived, in which the rater was asked to rank the requirements by the paired-comparison method. A tabulation of the ranking then served as a basis for the optimum design.

In the design of the questionnaire, controls were incorporated for the variables caused by the mechanics of construction of the paired-comparison rating form as well as for those caused by the psychological attitudes of the raters. The previous experience of the raters could not be controlled, but a tabulation of this experience was made to test the assumption that all of the desired degrees of climatic and organizational experience would be sampled even though the raters were presently stationed at one headquarters. The tabulation of the result indicated that the assumption was valid.

The questionnaires were distributed among personnel at Third Army Headquarters, Fort MacPherson, Georgia. By the nature of the general activities of their branches of the service these persons were considered to be intimately connected with the supply of petroleum products. Each section provided a contact officer who distributed the questionnaires within his section, collected them when completed, and returned them to the writer. A rate of return of 57 per cent was obtained. No instructions other than those on the written questionnaire were given except where absolutely necessary concerning the mechanics of completing the rating.

The individual choices indicated in each pair were tabulated on a matrix, and a preference index was computed for each requirement with respect to each other one. From these data a mean preference index was computed which served as the value from which the relative ranking was established. The results were analyzed statistically to ascertain whether or not the differences in mean preference index values were significant. Generally, significant differences were obtained except for the differences between those requirements appearing in the central portion of the ranking scale. The presence or absence of a statistically significant difference was considered in the design of the container.

The optimum size and shape for the container were then determined by a process of inductive reasoning based on the relative importance of the requirements. The optimum size was determined first, and was limited primarily by the importance of the ability of the container to be lifted by hand. The limiting weight was established at 110 pounds, which allowed the selection of a 15-gallon container. With this size in mind, a cylinder was selected as the optimum shape because of its ability to satisfy the more important requirements. Further computations revealed a 15-inch diameter and a height of 19.75 inches to be the optimum dimensions for the container contingent upon seam design and closure design, which were beyond the scope of this research.

CHAPTER I

INTRODUCTION

Description of the problem.--Petroleum supplies are extremely critical to all branches of the service in modern warfare. Gasoline, Diesel fuel, kerosene, motor oil, and lubricating oils and greases are the petroleum products which are widely used for the many vehicles and equipment units organic to the modern army. The rate of consumption of these products increases with the development of new techniques of troop movement, supply movement, and with the increase in requirements for the construction of tactical structures and facilities inherent in these techniques. Even the more modern infantry weapons must have vehicular transportation to provide the necessary mobility for effective employment. It will be apparent in the development of this paper that the great volume of petroleum products used in these instances presents a major problem in materials handling to the supplying service, the Quartermaster Corps.

In particular, the handling problem is critical in the more forward areas where the employment of mechanical equipment is limited by tactical considerations. Also, the amount of handling is increased since the using units, which must be mobile, are unable to store large reserve supplies. Rather, they must draw daily enough gasoline, Diesel fuel, etc., to keep all vehicles in operation for a 24-hour period. It is the purpose of this research to examine the containers presently being used, along with the existing and probable methods for handling them, to develop critical requirements for the design of a container that will help to minimize handling difficulties. The relative importance of these requirements will then be established from solicited opinions of persons experienced in handling petroleum products under field conditions. The results of a questionnaire serve as a basis for determining the optimum size and shape for the design.

Handling petroleum supplies in the theater of operations.--The present methods of handling petroleum products utilize widely diversified forms of transportation and procedures for handling at the various stages of the supply line. Water transportation, usually in the form of tankers, is used to bring bulk supplies into the theater of operations. Upon arrival at the port, it may be pumped into large storage tanks through underwater pipelines or it may be off-loaded into tank trucks, cargo trucks, rail cars, or barges for transportation to the base depot. In some cases, dockside pipelines are used although this method is not as popular as the others.[1] From the storage tanks at the base depot, which are used as relatively permanent storage areas for the theater of operations, these products must be transported to forward depots for bulk reduction and issue to the using units. The transportation will be one or more of those forms previously listed, depending upon the availability of each, the quantity to be moved, and the tactical situation.

The operation of canning the bulk supplies may be accomplished at the base depot or at the forward bulk reduction point. There are a few minor differences in the operation at the two locations with respect to tactical considerations, but the materials handling procedures are essentially the same. Two shifts of personnel, each working eight hours, man the operation in four subareas: the unloading area, the drum cleaning area, the dispensing area, and the stacking area.[2] Empty containers are off-loaded at the unloading area and are transported by roller conveyor to the drum cleaning area. There they are cleaned and inspected. This part of the operation is carried out in a mobile drum cleaning plant mounted on two semi-trailers. After cleaning, the

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[1]Quartermaster School, U. S. A. R. Schools Instructor's Guide, Quartermaster Course, Third Year Basic, Vol. II (Fort Lee, Virginia, 1954), p. II-5.I.

[2]U. S. Department of the Army, Quartermaster Petroleum Depot Company, FM 10-37 (Washington, 1952), pp. 165-168.

empty drums are placed on a roller conveyor for transportation to the dispensing area and ultimately to the stacking area. All equipment is mobile.

Before describing the stacking operation, it might be well to consider the characteristics of the standard containers that are presently used. Fifty-five gallon drums are used for convenience of handling. A filled drum weighs approximately 400 pounds, and a 2 1/2-ton truck can transport 18 such drums. The recommended method of delivering petroleum to the using unit, however, is the five gallon can, which weighs 42 pounds when filled. One hundred and twenty-five of these cans may be carried by a 2 1/2-ton truck, and 40 may be placed in a one-ton trailer.[3] Lubricants other than gasoline are issued in a variety of container sizes from one quart cans to 55-gallon drums.

The dispensing area operation for the two most common sizes of containers, the 55-gallon drum and the five-gallon can, requires the employment of a three-man team. One man removes the bungs from the container. The second man fills the can or drum, and the third man replaces the bungs. After the bungs are replaced, the containers travel over a roller conveyor to the stacking area. The handling equipment used in the stacking area may be either mobile cranes or standard

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[3]Quartermaster School, op. cit., pp. II-5.4, 5.5.

A-frame attachments that are mounted on the front of a 2 1/2-ton truck. At times manhandling may be required where the above equipment is not available.

Five-gallon cans are stacked upright on their bases in blocks no more than 50-feet square, and not more than four cans high. This stack is called a section and must have 30-foot aisles on all sides. Nine sections make up a block, which must have a 150-foot aisle on all sides. A similar system is used for the 55-gallon drums except that they are stored on their sides. They are placed butt to butt, with bungs and vents toward the outside, no more than three drums high. They are placed in rows so that the total number of drums in a three-layer row is 300. Twelve such units make up a section, and the required aisle width around the perimeter is 150 feet.[4]

From the forward bulk reduction area the individual containers are transported to the using unit. No materials handling equipment is organic to these units as a general rule, which necessitates manhandling for storage and for refuelling individual vehicles and equipment. This requirement, to a great extent, has been a limiting factor in the design of the present containers. It is felt by Quartermaster Corps research personnel that the five gallon cans

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[4]Quartermaster School, op. cit., p. II-6.8.

may be easily carried, and that the 55-gallon drums may be rolled. In possessing the quality of being manhandleable, the petroleum containers are placed in the same category with the bulk of military packages.[5] That is, a great amount of handling is necessary in the using units where there is virtually no handling equipment available.

Characteristics of a military package.--The vast amount of supplies that must be handled in a theater of operations presents a departure from commercial packaging principles. There are other departures that must not be overlooked. For instance, the utilization of space in shipping has an increased degree of importance. Also, the possibility of having inside storage facilities is practically unheard of, the packages are frequently subjected to unusual stresses in transit, and military stores often spend an excessive amount of time in storage. As previously cited, the handling equipment at the destination dictates the size and weight limitations of the package unit, whereas shipping charges or some other economic factor is of greatest importance to size determination in civilian practice. Experienced operators for materials handling equipment are available to the civilian firm, which allows a more precise degree of

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[5] J. E. L. Carter, "Mechanical Handling of Military Stores in a Major War," Mechanical Handling, XXXIX (September 1952), pp. 426-430.

planning regarding the manner of handling than is possible in the military, where these operators are young and relatively inexperienced. However, the one difference that is most vital in the design of the military package is the immeasurable value of the product if it is lost when needed.[6]

In addition to the preceding characteristics, the criteria used in determining the number of items per package are: weight, cube, maximum dimensions, minimum quantity required in normal use, frequency of use, minimum quantity that will afford an efficient pack, and, if possible, ability to facilitate inventorying by packing in multiples of ten.[7] Of course, these criteria are for general supplies and additions, deletions, and alterations must be made to facilitate the supply of a particular item in a given situation. The item of supply under consideration, petroleum, has its own set of package requirements, which should be developed from the above list as an initial step in designing a container.

Organization of Quartermaster Petroleum Supply Units.--The prevalent type of petroleum supply unit assigned to the rear areas of a theater of operations is the Quartermaster Petroleum Depot Company. The principle items of equipment

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[6]Tom Wharton, "Packaging Program for the Military Department," Flow, VII (March 1951), pp. 79-80, 82, 84.

[7]"A Practical Manual of Material Handling Procedures," Flow, X (May 1954), pp. 79-82.

organic to this unit are listed in Table I.[8]

Table I. Equipment Organic to Quartermaster Petroleum Depot Company

Type of Equipment	Number Authorized
Crane, crawler, 5,000-lbs. cap., 7-ft. rad., 12-18 ft. telescoping boom	2
Fork truck, drum handling attachment, 3-drums	1
Fork truck, gasoline, 4,000-lbs. cap., 114-in. lift	1
Sling, barrel chain, 3-pronged	4
Conveyor, roller, 18-inch by 10 feet long	15
Conveyor, roller, 18-inch, 45 degree angles	12
Conveyor, roller, 18-inch, 90 degree angles	12
Pump, 50 gpm	1
Tank, storage, 750-gallon, skid mounted	6

The capabilities of this unit include: operating a bulk storage of 100,000 to 200,000 barrels; maintaining a reserve of 100,000 gallons in five gallon cans; cleaning, filling, and issuing 20,000 five gallon cans daily; and shipping an additional 400,000 gallons of bulk petroleum products daily.

The Quartermaster Petroleum Supply Company is the unit that operates the more forward supply points and bulk reduction points. Its materials handling equipment must be more mobile and, as a result, is less elaborate. There are

[8] U. S. Department of the Army, Table of Organization and Equipment 10-377A (Washington, 1954).

no cranes or fork trucks organic to this unit. The A-frame kit mounted on the front of the 2 1/2-ton truck is the chief item for drum handling. There are twelve of these kits available. A three-pronged barrel chain sling is attached to each A-frame for lifting the drums. The other principal item of handling equipment is the 600-gallon fuel-servicing trailer. There are twelve of these trailers organic to the unit, which allows delivery of bulk supplies to using units as required. The capabilities of this unit include: cleaning 22,500 cans per day; packaging 60,000 cans per day from bulk; distributing 4,400 five gallon cans per trip, or distributing 600 fifty-five gallon drums per trip.[9]

The capabilities of the using unit must be considered also since it is normal for that unit to pick up petroleum supplies at the bulk reduction point rather than have them delivered to the unit area. The most prevalent type of transportation organic to these units for cargo hauling is the 2 1/2-ton truck. This vehicle can carry 350 empty five gallon cans or 125 full five gallon cans. If 55-gallon drums are used, the capacity of the vehicle is 18 full drums. In some cases, the use of railway boxcars may prove advantageous.

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[9]Quartermaster School, R. O. T. C. Instructor's Guide, Quartermaster Course, MS III, Vol. II (Fort Lee, Virginia, 1954), p. 710.

The capacity of these cars will average 1,700 filled five gallon cans or 3,200 empty ones.[10]

Recommendations for handling standard containers.--When manhandling of 55-gallon drums becomes necessary, the Quartermaster Corps offers recommendations for the use of devices such as skids, ropes, cranes, or A-frames.[11] A precaution is cited that care must be taken to avoid damage which might lead to subsequent leakage. The practice of dropping drums from the rear of trucks should be forbidden as it will surely result in such damage. The procedure recommended if this act is absolutely unavoidable requires the placing of a salvage tire on the ground to function as a shock absorber.[12] Once the drum is on the ground, the problem of moving it to storage or dispensing points is usually solved by utilizing its ability to be rolled. When the five gallon can is used, lifting is possible, and it is uaually carried by one man from place to place as required.

Manual handling.--Various methods of manually handling drums are suggested in Army publications, including rolling, lifting, and sliding. Other methods that might prove advantageous

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[10]Quartermaster School, U. S. A. R. Schools Instructor's Guide, Quartermaster Course, Third Year Basic, Vol. II (Fort Lee, Virginia, 1954), p. 11-5.5.

[11]Quartermaster School, R. O. T. C. Instructor's Guide, Vol. III, p. 32.18.

[12]Quartermaster School, U. S. A. R. Instructor's Guide, Vol. II (Fort Lee, Virginia, 1954), p. 11-6.8.

are: the use of hand trucks, barrel cradles, or hand lift trucks. While the use of these items of equipment would undoubtedly save time and effort, a more complete analysis of the investment required might prove this to be an unnecessary expenditure. This fact might be especially true in the military situation since the handling of petroleum supplies and other supplies in the using unit is not a primary function and is necessary at irregular intervals.

Since it appears from the foregoing discussion that lifting may become necessary in handling containers manually, especially when five gallon cans are used, a safe method must be employed. This method should allow the person to get close to the load, yet have adequate room in which to work. He should have a firm footing with the feet placed approximately 12 inches apart. The back should be kept as erect as possible during lifting with most of the work being done by the legs. The load should be taken on slowly, using care not to turn or twist the body while under the load. The safest method of carrying a load is to keep it close to the body with the arms at full length.[13] It has been found that accidents during manual handling operations increase in rate of occurance and in severity with an increase in the weight

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[13] V. R. Crosswell, "Medical Examinations and Instructions for Lifting without Strain," Industrial and Engineering Chemistry, XLIII (September 1951), sup. 129A-130A.

of the object to be lifted and with an increase in the distance the object is to be moved. In fact, some states have laws which permit a woman to lift a maximum of 25 pounds, while the maximum weight allowed to be lifted by a man is 70 pounds.[14] In the Army, this weight value is extended to approximately 100 pounds. The basis for this statement will be presented in a later chapter.

Mechanical methods of handling drums and cans.--The trend in industry during the post war period has been to replace manual handling with various pieces of mechanical handling equipment. In practically every instance total handling costs were reduced. In addition, there was a definite reduction in the amount of manpower required. If the military, by adopting the principle of widespread use of mechanical materials handling in the depot areas, could realize these savings, the result should follow that more men might be relieved of rear area duties and be available for front line combat duty.

The results of a survey of materials handling equipment in use that will handle drums and cans reveals that conveyors, portable elevators, industrial power trucks, cranes, fork trucks, gasoline motor trucks, and straddle trucks are all being used in various situations at a savings in effort and money to industry. A number of

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[14] "A Practical Manual of Material Handling Procedures," loc. cit.

special attachments have been developed for drum handling with these types of equipment. For example, the detailed description of ten different attachments for the fork truck were obtained. One, the drum carrier, handles four drums at a time, grasping them at the top and carrying them in a vertical position.[15] Others, the horizontal drum clamps, the "Drum Up-ender," and the double curve arms, will handle two drums at a time. The "Drum Up-ender" allows rotation of the drum for stacking and emptying.[16] The Shell Oil Company has developed side clamp arms that also allow the handling of four drums simultaneously.[17] Most organizations, however, utilize pallets and the standard fork truck, allowing them to transport four drums at a time. This latter practice also allows the fork truck to be used for moving supplies of other types since there is little lost time due to changing attachments.

Along with the principle of mechanizing the handling of materials, industry has also utilized the efficiency that comes with handling supplies in unit loads. This efficiency is a result of the lessening of the physical effort required to move a given volume of supplies, as well as the subsequent

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[15]"15 Truck Handling Attachments," Mill and Factory, XLVIII (April 1951), p. 110.

[16]Ibid.

[17]"Palletless Handling Preferred," Canadian Chemistry and Process Industries, XXXVII (October 1953), p. 58.

reduction in man hours required. Better storage facilities become available, better inventory control is maintained, and there is usually a minimum of damage in transit, all of which serve to make efficient handling a reality.[18]

The employment of unit loads has usually meant the requirement of pallets. There are many types of pallets in wide use that vary in design from throw-away pallets made of cardboard or other material to wooden pallets that are semi-permanent in their lasting ability. Recently, more permanent metal pallets have come into use, however. One such pallet that is presently being used to transport drums is formed from flat structural steel bars to form a grillage that provides slots for the forks that may be inserted from any side. The capacity of the pallet is four drums.[19] This pallet also conforms to the dimensions recommended to be used as standard sizes by the National Bureau of Standards. These recommended dimensions are 40 inches by 32 inches and 48 inches by 40 inches.[20] It is believed that these sizes will allow the pallets to be used in any form of carrier with a minimum of wasted space.

New Developments.--In addition to the methods of materials

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[18]"Load Units Save Money," Flow, VII (May 1952), pp. 106-109.

[19]"Reversible Steel Pallets Used for Handling Drums," National Petroleum News, XLIII (June 6, 1951), pp. 68-69.

[20]"Standardization for Palletization," Modern Packaging, (August 1950), pp. 86-89.

handling previously cited, all of which have been tested and found satisfactory by industry or by the Army, there are other methods in the test period of development which are worth mentioning. For instance, a synthetic rubber fabric, collapsible, 55-gallon drum has been put into production. It provides the user with a space saving feature on return shipments. It is comparatively light in weight and will absorb shocks that would destroy or damage metal or fiber drums. The empty weight is 30 pounds, and it can be rolled, lifted, and easily stored.[21]

Another rubber fabric petroleum container that is still in the experimental stage is the free-fall, five gallon container. This container is presently being developed by the Army. The basic intended use for this container is in aerial delivery to troops on the ground, possibly behind enemy lines. Its adoption requires meeting standards of free-fall delivery without sustaining damages that will cause leaking, of being adaptable to the standard nozzle presently in use, of allowing the delivery of the contents free from contamination and of being capable of being handled by one man wearing mittens. A 12 pound, disc-shaped, container with a yellow skirt four inches wide to aid in the location of the container on the ground has been tested. The

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[21] "Collapsible Drum," Modern Packaging, (April 1951), p. 89.

result of the tests on pilot models were satisfactory, but the ones that were mass produced exhibited an excessive amount of failure. Adjustments are being made.[22]

Improvements are also being sought for the metal drums that are in such wide use today. The standard round rolling hoop has been replaced in some industries with a steel I-beam that protrudes from the side of the drum about one and one-quarter inches.[23] This adjustment is intended to reduce the damage caused by normal rolling and especially that caused by dropping the container. However, the area of research that has been of most interest to the Quartermaster Corps seems to be in the development of a closure for the metal drum that will minimize contamination to the product.

Research is underway concerning the development of a rough terrain fork truck. Heretofore the inability of standard models to travel over terrain peculiar to the combat situation while under load has prevented adoption of this item of equipment for forward area use. It is recognized, however, that this item of equipment could be a valuable one to have because of its versatility, providing the disadvantage cited could be overcome. During the recent years the Army Transportation Corps, in conjunction with the

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[22] U. S. Department of the Army, Quartermaster Research and Development Technical Progress Report (Washington 1954), pp. 490-491.

[23] "Returnable Metal Drums," Chemical Engineering, LVIII (January 1951), p. 210.

Ordnance Department, has been testing a proposed rough terrain fork truck. It is an adaptation of commercial models. Ten trucks were sent to the Far East Command for operational testing. The results were not altogether satisfactory since major failures occurred in the axle and transmission assemblies. Repair parts have been fabricated, but it is felt that there are still too many functional and engineering deficiencies in this item to justify adoption and standardization unless there is an extreme emergency. Preliminary design has been completed for a fork truck with the characteristics of traction-floatation mechanism with epicyclical drive, movable counterweight, and load traction. Its capabilities will include the ability to operate over rough terrain, mud, and sand, yet have the ability to attain a relatively high speed on improved roads, and be constructed to absorb rough treatment for a long period of time.[24]

Research has also been conducted in the area of container design by the Quartermaster Corps. A reusable container for shipment of 55-gallon drums of a collapsible type has been developed. It is shipped in an unsheathed wooden crate that will hold ten collapsed, prefabricated 55-gallon drums for overseas shipment and storage. The drums are intended to be reformed at the destination from a collapsed cylindrical body, a head section, a base section, and

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[24]U. S. Department of the Army, <u>op.cit.</u>, pp. 444-445.

two chimes bands.[25] Effort has also been directed toward finding a substitute material to use in the fabrication of the container. Rubber impregnated fabric, fiberglass, aluminum, and magnesium have been tested. The rubber impregnated containers have not proven satisfactory to date due to the high cost and the difficulty of handling. The fiberglass containers were found unable to withstand rough handling. Designs have been prepared for the use of aluminum and magnesium. Magnesium, however, has not been fully evaluated as a material to be used in contact with some fuels, and the cost is excessively high.[26]

Research problems related to handling petroleum products.--The Quartermaster Corps is anticipating that future research regarding petroleum supply procedures will deal with grading the product, with the use of fuels under varying climatic conditions, and with the size, shape, and composition of containers.[27] This last problem seems to be of vital interest to members of using units who must move existing containers manually. Drums are designed to be rolled, but altogether too frequently lifting becomes necessary. The weight of the present container, approximately 400 pounds, is excessive for this purpose. The five gallon can is

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[25]U. S. Department of the Army, Quartermaster Research and Development Technical Progress Report (Washington 1951), p. 477.

[26]Ibid., p. 25.

[27]U. S. Department of the Army, R and D Technical Progress Report (1954), p. 376.

supposed to answer this problem, however, some consideration has been given to increasing the size of this container to seven and one-half gallons. This increase can be made by retaining the top and bottom design and merely lengthening the body of the can. A considerable saving in steel would result, as well as a savings in time in filling and cleaning the cans. The main objection to such an increase in size would be the additional weight to be manhandled by the soldier. In addition, transportation and stacking problems might be increased. The design is still being studied.[28]

[28] U. S. Department of the Army, R and D Technical Progress Report (1951), p. 26.

CHAPTER II

DEVELOPMENT OF THE PROBLEM

Problem areas for consideration.--In the discussion of present handling methods for petroleum products in the preceding chapter, it is apparent that the supply line for these products is a lengthy and complicated one. The length is necessary since the source of supply and the user in the theater of operations are often located in different parts of the world. The procedures become complicated by the wide variety of transportation facilities that must be used to meet the demands of the situation. Sometimes petroleum products are shipped into the theater of operations in tankers; sometimes freight ships are used. In the latter method, the petroleum products are stored in individual containers. The method of arrival of the supplies will influence the methods of handling in the base depots to a great extent. Underwater pipelines, dockside pipelines, or various land transportation facilities may be utilized in moving the products to these depot areas. In some cases, the products may be moved as far forward as possible, bypassing the base depot entirely. It can be seen, therefore, that handling procedures prescribed for this area must be flexible to allow the maximum use of mechanical equipment or pipelines as permitted by the situation.

In the more forward areas, the feasibility of employing mechanical handling methods becomes more difficult. This characteristic is partially caused by the fluid tactical situation that exists and partially by the nature of the terrain on which supply operations must be conducted. This terrain is generally rough, and there is usually little time available to improve it. As a resutt, the handling of supplies becomes more a manual operation as the location of the unit approaches the area of intense combat. In bulk reduction areas a portion of the handling is accomplished by mechanical methods. The units in these areas as well as in the storage areas have the A-frame kits which are mounted on the 2 1/2-ton trucks to function as a crane. Roller conveyors are also available to use in the horizontal movement of supplies. In issuing the petroleum products to the using unit, however, more manual labor is required. This labor may well be indigenous personnel or prisoners of war, but the manual methods must be used. In handling the supplies in the using unit area, manual methods are employed almost exclusively. Rarely will the using unit have an item of materials handling equipment at its disposal in the unit area.

Area chosen for thesis problem.--There are many points along the line of supply that might be considered worthwhile investigating insofar as the effect of resulting improvements causing a net increase in the efficient movement of petroleum products. However, the experience of the writer as a member of a using unit has served to intensify the interest in the forward area operations as compared to others. Another factor leading to the choice of the combat zone as the area of consideration for this thesis is the absence of organic mechanical handling equipment. Justification for this condition was cited in the preceding chapter. A third factor is the degree of similarity between handling petroleum supplies and handling materials of construction where mechanical means are limited or non-existent. In both cases there is an interrupted flow of materials, which causes a great waste of time where materials handling equipment must remain idle while awaiting the arrival of supplies to be moved. The excessive amount of time that is nonproductive in these situations usually results in an extremely high cost for materials handling. However, heavy items must be moved or lifted, causing manual handling to become extremely difficult, if not impossible. When manual methods are not possible, the decision to use mechanical handling equipment regardless of the operational cost becomes necessary and is relatively easy to make. It is in the case where manual handling is possible, but extremely difficult, that this decision becomes a matter for debate. The usual decision is heavily influenced by the economy factor, and in the past it has often caused the factors of safety and of manual effort required to be overlooked. Even though the trend not to make hasty decisions in such instances is becoming an accepted practice, the cost of idle equipment is a large item of expense in any operation that warrants a great amount of attention. In the situation in question, the lack of equipment that is able to perform under field conditions has also been a factor that has influenced the continued use of manual handling. The low cost of labor is another contributing factor, but it is expected that the tactical advantages realized from speedier handling would lead to the adoption of mechanical methods if it could perform adequately. A savings in manpower would also result and would release more men for combat duty.

Specific methods for the improvement of petroleum handling techniques.--In addition to a possibility of improving handling equipment so that it may be usable on rough terrain, there are other ways of improving the techniques of handling petroleum products. One such area for study might be the improvements of existing methods of storing and issuing the supplies. The prescribed layout for the bulk reduction point might be improved. The stacking height might be reduced. There are a number of places in the supply line that are potential areas for improvement of handling methods.

Another facet of the problem in which redesign might well show an improvement in material handling is the remodeling of the containers. As cited in the preceding chapter, the containers presently in use are not ideal in meeting the demands of the users. It was further stated that future research in this area might improve the handling efficiency. The chief disadvantage of the 55-gallon drum is its weight, which limits its flexibility during manual handling. The five gallon can was intended to overcome this disadvantage, but introduced a new problem. It requires a great amount of handling to meet the volume requirements of the user. Other problems exist and will be developed during the remainder of this chapter since the design of an optimum container for field use has been chosen as the specific problem for research and reporting in this paper. The design will be approached with emphasis on handlability in the critical areas, the forward area supply point and the area of the using unit.

Development of requirements for the optimum container.-- Probably the most logical approach to the design of any item requires an initial determination of the exact functions it is expected to perform or conditions it is expected to meet. In the case of a petroleum container that is used in the field by the Army, these facts can be readily discovered by tracing the path it travels from the bulk reduction point to the using unit and back for refilling. Initially the five gallon can is inspected by a non-commissioned officer at the bulk reduction point before it is filled. It must be free from rust or other foreign matter that might contaminate the contents. It should also be perfect as far as the absence of dents and/or holes is concerned, since the presence of either type of defect could cause subsequent leakage. If the can is found to be in satisfactory condition, it is placed on a roller conveyor for transportation to the filling area. Some manhandling is necessary to place cans on the conveyor and to remove them from it for the next operation. If the can is rejected, it must be carried to a storage area to await transportation to a salvage depot. Of course, if the reason for rejection is the presence of rust, dirt, or other foreign matter, the can must be transported by hand or by conveyor to the drum cleaning plant. Once it is clean, it is taken to the filling area.

The usual method for filling cans in the forward area is the three-man method described in the preceding chapter. Some manhandling is required where the cans must be removed from the conveyor during this operation. The filled cans are transported by roller conveyor to the storage area where they are stacked as previously described. For the most part this stacking will be a manual operation. There are two types of storage depending upon the expected length of the delay in this area. Cans placed in temporary storage are intended to be issued to using units upon call. A reserve supply must also be maintained as previously discussed, and is placed in an area for relatively permanent storage. In both areas outside storage is a mandatory condition caused by the tactical situation, which means that camouflage of the supply must be considered.

From the temporary storage area the filled cans are issued to the using units. The basis for issue is one full can for every empty one that is returned to the supply point by the unit. It is the general rule that the transportation for this issue must be furnished by the using unit. The carrying capacities for the cargo hauling vehicle and trailer which is usually used for this purpose was presented in the previous chapter (125 cans for the 2 1/2-ton truck and 40 cans for the one-ton trailer). Manual loading methods are employed at the supply point.

Upon arrival at the using unit the cans must be off-loaded and stacked in the proximity of the motor pool area, yet far enough from existing structures or tents not to create a fire hazard. All handling during the off-loading, the stacking, and the refuelling of vehicles and equipment is accomplished manually. The number of men available for these operations will vary with the type of unit, the time of day, and other factors peculiar to the individual situation. In some cases the truck driver may be the only person readily available. Refuelling the vehicle at the beginning of the day is usually accomplished by the driver. There may be an additional man from the motor pool present, but his primary duties will pertain to the recording of the amount of fuel dispensed to the individual vehicles and items of equipment so that accurate supply records may be kept. These duties may warrant enough attention to prevent his participating actively in the refuelling operation.

Other items of organic equipment that require fuel of some type are the space heaters, water heaters, and cooking stoves. The handling is again a manual operation wherein the cans must be carried from the storage area to the individual tents or buildings. The distances involved will vary, but in most cases will not exceed 100 yards. The cans must be lifted during the refuelling of the space heaters to provide gravity feed to the heater. This height is usually three feet to five feet. All empty cans must then be returned to the storage area where they will be loaded on a 2 1/2-ton truck for return to the supply point.

If the 55-gallon drum is used for issuing petroleum products to the using unit, the same sequence of moves is followed. The differences that enter into the procedure are with respect to the procedures of handling made necessary by the additional size and weight of the container. For instance, the empty drums may be moved within the supply point by either of three methods. They may be transported on the roller conveyors, or may be rolled, and when absolutely necessary, they may be lifted. The filled drums are handled by engaging the hooks of the barrel slings over the rolling hoops at either end of the drum. Three drums are grasped in this manner and are moved simultaneously, using the A-frame kit for the 2 1/2-ton truck as a crane. Eighteen drums are loaded on the truck in this manner for transportation to the using unit.

In unloading the drums from the 2 1/2-ton truck in the motor pool area of the using unit, it is recommended that boards be placed at the rear of the truck to form a ramp down which they may be rolled. This procedure will minimize damage to the drum. The drum may be dropped from the rear of the truck providing a salvage tire is placed on the ground to cushion the shock. These methods are prescribed by the Quartermaster Corps to extend the useful life of the drum. However, members of the using units who are anxious to get the drum in storage as quickly as possible and with as little effort as possible will usually resort to dropping the drum from the rear of the truck onto the ground. This practice is not condoned, but will frequently be used unless the handling is closely supervised. Horizontal movement is accomplished by rolling the drum.

The recommended practice for refuelling vehicles and equipment includes the construction of a wooden rack for the drum by the using unit.[1] This rack allows the drum to be raised sufficiently high respect to the height of the gasoline tank of the vehicle to permit gravity flow from the container into the tank. A ramp must be constructed on one side of the rack to allow the drum to be rolled into position. The number of men available to handle the drums during these operations varies as previously discussed. However, it is the usual

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[1]The Engineer School (R. O. T. C. Special Text 35-4), Vehicle Maintenance and Motor Movements (Fort Belvoir, Virginia, 1953), p. 41.

practice to have more than one man available.

The refuelling operation for the organic equipment other than vehicles is accomplished after rolling the drum to the location of the equipment. Gravity feed is mandatory for space heaters, which requires raising the drum. Ramps are constructed for heights greater than two or three feet, but the usual practice is to lift the drum onto the rack, one side at a time, if this height is not so great. The empties must be returned to the supply point as was done with the five gallon cans. Where lifting is required for loading the truck two men can handle the drum easily. As previously cited, one man can lift an empty drum if the situation demands that it be done.

One fact that seems apparent from the foregoing discussion is that manual handling of petroleum containers is necessary. In the course of the handling both horizontal and vertical moves are required. Horizontal moves are made both in the supply point and in the using unit. Vertical moves seem necessary in storage to conserve space and allow better control over the supply operation. In many cases vertical movement is necessary to place the container on the roller conveyor for horizontal movement from area to area in the supply point. It has been stated several times that gravity feed for refuelling vehicles and equipment is required. This is another instance where a vertical move is used. Finally, the loading and off-loading operations in the using unit require vertical movement. Attempts have been made, as described, to reduce the difficulties encountered in making these moves, but some of them still exist.

The distance of the moves is a factor that is not easily controlled since tactical considerations require dispersion of troops and facilities. The methods to be used in moving supplies are not completely controllable either because of these same considerations. The methods suggested in the preceeding chapter include: lifting, sliding, rolling, the use of ropes and a ramp for rolling, manual rolling up a ramp, and dropping, although the latter method is suggested as an expedient, not as a normal practice. Some are more desirable for use than others because of the amount of effort saved, but it would seem that none of the less desirable ones may be eliminated entirely in the existing condition and while using the existing containers.

Another evident fact that is important to the design of a container is that outside storage is mandatory. This type of storage allows the container to come in contact with sources for contamination of the product. Dirt, dust, and moisture are the chief sources for contamination which will hinder the performance of the product as a fuel for combustion. Rain or runoff might enter the container through damaged seams or through the fabricated holes in the top of the container. Moisture might also form inside the container if there is a great degree of fluctuation in outside temperature. Once moisture reaches the inside of the container, it may form rust or not, depending upon the length of time before the container contents are used and upon the condition of the interior surface. The formation of rust, however, is not vitally important in this instance since the moisture itself will contaminate the product if it is present in sufficient quantities.

The use of outside storage does allow freedom of movement in issuing and storing the petroleum products, which is a point in its favor. Its use would prove advantageous to the use of mechanical handling equipment in that no height restrictions would be present. Of course, the difficulty in traveling over rough terrain has limited the variety of types of mechanical equipment that may be used, and has served to necessitate the use of a great amount of manual handling.

Other pertinent facts that should be considered include the practice of using the 2 1/2-ton truck as the principal vehicle for hauling the products to and from the using unit. The hauling volume is limited, therefore, by the volume and weight capacity of this vehicle. Also an economy of space is desirable during storage and during transportation in getting the product to the bulk reduction point as cited in the previous chapter. In filling the containers, it is necessary to ground them against static electricity which is created.[2] Finally, the tactical situation demands that all installations be camouflaged to prevent detection from the air and from the ground.

Requirements for the design of an optimum container.--
In stating the requirements to be met by a petroleum product container, consideration must be given to several design factors. Essentially the factors could be the size, the shape, and the material which best satisfy the requirements. The requirements which pertain to the determination of the optimum size will also pertain to the determination of the optimum shape to a great extent since the two design factors depend on one another and cannot be considered individually. The requirements for selection of the best material are separate to some extent, although the selection of the material will depend upon the size and shape container that is to be used. Therefore, the requirements that pertain to the size and shape will be studied before those that pertain exclusively to the determination of the material.

In considering the requirements which the container must meet that will tend to limit the size and shape of the design, the first apparent fact is that it must possess the ability to be moved manually. This manual movement may necessarily be in the vertical direction, i.e., lifting, or it may vary from the horizontal direction to a direction

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[2] U. S. Department of the Army, Handling Petroleum Products TM 10-466 (Washington, 1946), p. 20.

very close to vertical, in which case some means of gaining mechanical advantage may well be employed. This mechanical advantage may be gained by rolling or sliding if manual handling is necessary, or it may be gained by using mechanical equipment. The necessity for storing the containers in heights of more than six feet would require the individual to assume awkward positions for manual handling, and, if this requirement is of vital importance, might indicate that the development of adequate mechanical equipment is necessary. Related to this requirement is the ability to minimize voids during storage and during transportation, which would reduce the total storage space for depot areas and would allow maximum efficiency in the use of space during transportation between areas. It must particularly meet the requirement of being able to be transported in a 2 1/2-ton truck with a minimum of wasted space, yet, when the product reaches the using unit, the volume requirements there should be able to be met with a minimum amount of handling. It is particularly important that this requirement be considered since the bulk of the handling in this area is done manually.

There are other considerations which must be satisfied in the design of the optimum container, but their principal area of application is in determining the material from which the container should be made. It must be able to withstand the effects of outside storage that are caused by exposure to severe extremes of temperature, by exposure to moisture, and by exposure to sources of contamination of the contents. It must also be able to withstand constant contact with rough surfaces during moving or handling. It will undoubtedly be subjected to sudden stresses frequently during handling and should be able to withstand this treatment. Other requirements include the ability to be grounded against static electricity and the ability to be camouflaged.

It is the hypothesis of this thesis that an optimum size and shape can be determined for the design of a container for petroleum products that will best satisfy the existing handling requirements under field conditions. The requirements listed above will serve to evaluate the design after the relative weight of each is determined.

CHAPTER III

DESIGN PROCEDURE AND APPARATUS

General procedure for evaluating design characteristics.--The optimum size and shape for the container depends on the relative importance of the requirements established in the preceding chapter. A questionnaire which was completed by Army personnel served to solicit the opinions of experienced persons regarding the importance of these requirements. The questionnaire contained a list of the requirements which were to be ranked by the rater. The combined results of the many ratings then established a relation among individual requirements as to their importance. A statistical evaluation of the results was made. Various geometrical shapes and sizes were then evaluated as to how well each one satisfied the requirements. Where satisfaction of two requirements that are opposed to each other in their effects on the design presented a problem, the one of lesser importance was sacrificed to the degree necessary to permit an effective compromise. The end result was a one best size and shape that was used in the design of the optimum container.

Design of the questionnaire.--The basic part of the questionnaire consisted of lists of the requirements to be rated. Two separate lists of requirements were used. One list contained only those requirements that pertained to the determination of the optimum size and shape. The other list contained those requirements for selection of the material for the container. One reason for the use of two lists was that the two sets of requirements had little bearing on each other when the individual requirements were considered. When pairs were listed for the rater to select the more important requirement, the decision was very difficult since the statement of the task was ambiguous. There resulted a tendency to confuse the rater. It was also considered that there would be a source of error in the data thus acquired if the time necessary to complete the form was prolonged. The rater would tire and become more hasty in the selection of the more important requirements. The time could be reduced by using two short lists rather than one long list. The use of the paired-comparison method of rating made this fact particularly true since the number of ratings increases rapidly with each additional factor to be rated. This method was chosen, however, since it forces the rater to consider each requirement with respect to every other one. The result of this detailed consideration by the raters should be a more thorough analysis than is possible when other ranking methods are employed.

Even though steps were taken to insure that the raters made a thorough analysis and that their ratings were conscientious, the possibility of their tiring toward the end of the task might still be possible. To control the effects of this possibility on any one requirement the pairs were presented in a random order. This order was determined by assigning code numbers to each pair, and assigning the location of the pair on the questionnaire by the order of appearance of the code number in a table of random numbers. Another possibility for error to enter into the results because of order of presentation is the order in which the requirements were listed on the questionnaire prior to the accomplishment of the rating. This variable error was minimized by presenting them in an alternate high-low fashion after the probable order of importance was anticipated by the writer. A third cause for error due to order of presentation is the order in which the requirements are presented within each pair. The pairs were so constructed that each requirement appeared first and last in the various pairs a equal number of times.

There is another variable inherent in the rating method that might distort the results to a small degree. That variable is the ability of the rater to reflect on past ratings to assist him in making a present rating consistent with those preceding it. This variable is best controlled by using an interview in which the alternatives are presented verbally to the rater. He never actually sees the rating form. Thus, he is limited in his ability to recall how he rated a certain requirement previously while rating the one presently under consideration. This procedure, however, was not possible under the circumstances of this project since volunteer cooperation was necessary without interference with the normal duties of the raters.

In the construction of the questionnaire, care was taken to express each requirement in language that would not be misunderstood or confusing to the raters. The phraseology used was intended to express the requirement in broad terms so that fewer requirements might be used, yet complete coverage of the factors influencing the design would be retained. The instructions to the rater were stated as clearly and concisely as possible and were designed to be complete enough that the addition of verbal instructions would not be necessary. This act was intended to standardize the instructions to each rater so that the possibility of errors arising from one rater receiving more complete instructions than another might be minimized. It is recognized that it is extremely difficult to standardize verbal instructions since the degree of emphasis for every point in successive repetitions is practically impossible. Oral instructions were necessary in a few cases as to the mechanics of accomplishing the rating. These instructions were given as required, but were as brief as possible and did not include any discussion of the requirements to be rated.

The questionnaire was presented in four sections, see sample questionnaire, Appendix A. The first section contained instructions for accomplishing the rating. The purpose of the questionnaire was also included in this section along with instructions for the rater to base his choices on his experience. The last statement was an attempt to cause the rater to judge from the frame of reference with which he is most familiar.

The second section required the rater to establish the conditions under which his experience had been gained. One question concerned the climatic conditions under which this experience was gained so that later comparison might be made to determine the influence of the various climates on the design of the container. For the same reason another question was required to be answered concerning the organizational experience of the rater. As will be shown later, the assumption was made that the method of selection of raters would result in a variety of backgrounds being represented. These questions also served as a check on whether or not this end was achieved.

The third section contained a listing of the requirements pertaining to the selection of the optimum size and shape, while the fourth section contained the list of requirements which pertained to the selection of the material to be used. In each section additional instruction for accomplishing the rating followed immediately the list of requirements. After these supplementary instructions in each section, the pairs to be rated were presented. Repeat pairs were presented as a check on the consistency of the ratings.

These pairs were constructed of one requirement that was expected to be rated high and one that was expected to be rated low. This choice was expected to eliminate the possibility of getting a change in rating due to the fact that the requirements were of equal importance. The requirements in the repeat pairs were presented in reverse order from that already used to minimize the possibility of the rater recognizing the pair as a repeat. They were also located as far from the original pair as possible to help prevent recognition.

Selection of raters.--Army personnel,officers and enlisted men, who have had experience with handling petroleum products under field conditions were sought as raters. Forty raters were used. No attempt was made to control the experience of the raters. As previously stated, it was assumed that because of the frequent change of assignments of Army personnel, it would be possible to find a wide variety of backgrounds amoung the personnel presently located in any one assignment. It was further assumed that with a rather large sample this distribution of experience would closely approximate that of the Army as a whole. The conditions of the raters' experience were tabulated so that a check on the accuracy of these assumptions might be made.

The climatic conditions listed were frigid, temperate, semi-tropical, and tropical. These names should be familiar, except possibly semi-tropical, which is intended to include those areas located in the temperate zone that closely simulate tropical weather conditions with regard to temperature and precipitation during certain months of the year. The terminology is believed to be familiar to anyone who has served in such an area as well as those military personnel who may not have been stationed there but have come in contact with those who have. The organizational experience alternatives represented varying degrees of contact with the supply of petroleum products from practically none to actually working in a petroleum supply depot. The first alternative was for members of using units who actually had no direct contact with the supply of petroleum products. The second was for members of using units who were directly connected with handling petroleum supplies. The third was for those with experience as members of a petroleum product supply point at battalion level. The fourth alternative was for those raters who had worked in a supply depot serving a division or larger unit. The latter choice should apply principally to members of the Quartermaster Corps.

The instructions to the rater have been previously discussed as to the content, however, it should be pointed out that the intent was to stimulate the motivation for completing the choices conscientiously by explaining why the rater was chosen, and how his experience can be of use to the design. Of course, the mechanics of completing the questionnaire were also explained. Care was taken to insure that the instructions were standard for all raters. Verbal instructions were confined to explaining the rating procedure and were given only when absolutely necessary. As previously stated, the grammatical construction was designed so that the intentions of the writer might be accurately conveyed to the rater.

Two additional criteria were used in the selection of the raters other than their experience in dealing with the supply of petroleum products. The first was their availability, for this reason, personnel stationed at Third Army Headquarters, Fort MacPherson, Georgia were used. Further, personnel from the Quartermaster, Engineer, Ordnance, and Transportation Sections of the headquarters were sought in particular because it was felt that these branches are more vitally concerned with petroleum supply than others that might have been approached. Representatives from the Chemical Corps, Artillery, Infantry, and Signal Corps also completed questionnaires, but the chief contributors were the four branches previously mentioned.

The writer distributed the questionnaires through a contact officer in each office. This officer actually distributed the questionnaires to the members of his section. He also collected the completed ones. This procedure was suggested by the section chiefs. A more ideal procedure would have allowed the interviewing of each rater, but this method would have necessitated interrupting the regular work of the rater for purpose of conducting an interview at the convenience of the writer. In most cases this would have caused the rater not to give sufficient thought to his choices, and the overall spirit of cooperation would probably have decreased greatly. When all of the questionnaires in a section had been returned, the contact officer notified the writer, and they were collected for tabulation.

Tabulation of questionnaires.--The questionnaires were tabulated in the order of return to the writer. The repeat pairs were checked immediately for inconsistency. These pairs were then lined out to avoid duplication during tabulation of the other choices. A matrix was constructed for recording the individual choices. Then each questionnaire was tabulated by recording the individual choices in the appropriate square of the matrix. The results of this tabulation show the number of times any one requirement was chosen as being more important than each of the other ones.

The experience of the rater was tabulated on a separate sheet. As instructed, the raters circled every choice that described their experience. This practice was necessary since most of the raters had served in more than one type unit and in more than one theater of operations. The results enabled the writer to compute the percentage of the raters that had gained experience under each of the conditions listed.

The overall results were noted throughout the tabulation period as to the relative importance of each requirement. This observation was especially important at the end of each return increment. When it appeared that the requirements had ceased to fluctuate from one position to another for successive return increments, it was assumed that further distribution of the questionnaires was unnecessary. It was then possible to compute a preference index for each requirement. This computation involves dividing the total number of times it was possible to have chosen a requirement over another into the actual number of times this choice was made. The maximum value would be obtained if the requirement in question were chosen over another on every questionnaire. The individual preference indexes for each requirement were then totaled and the mean preference index was computed as the actual measure of the importance of that requirement. The values obtained as mean preference indexes were then used to rank the requirements in the order of their importance.

The standard error of the mean was also computed for each requirement. The New Multiple Range Test[1] was then used to test for significant differences in the preference indexes. This statistical analysis was also made for the comparison of the ratings of members of the Quartermaster Corps with those of the other branches of the service, as

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[1]David B. Duncan, Multiple Range and Multiple F Tests (Virginia Polytechnic Institute, 1955), p. 1-7.

well as to compare the indexes for the various climatic zones. These statistical comparisons were intended to determine whether or not the conditions described had any appreciable effect on the relative importance of the requirements.

The questionnaires were scrutinized for any indication of an order of preference tendency on the part of any rater. For instance, he could have chosen the first requirement in each pair without actually considering their relative merit. However, no such condition was indicated on any questionnaire.

CHAPTER IV

RESULTS OF THE QUESTIONNAIRE AND DISCUSSION OF THE RESULTS

Results

General.--The results were compiled in the manner described in the previous chapter. The matrices indicating the preference index for each requirement with respect to every other one are presented in Appendix B and Appendix C. The results that are of immediate importance to the design of the container are presented in this chapter. They represent the ratings on 40 questionnaires that were returned. Sixty-seven were originally distributed. This means that a return of approximately 57 per cent was achieved.

Results of tabulating the climatic and organizational experience.--Of the 40 raters, 80 per cent had had experience under field conditions in more than one climatic zone. In these cases each zone was credited. A similar effect was obtained with regard to the organizational experience of the raters. Two-thirds of the raters had gained experience in handling petroleum products under more than one type of organizational condition. Again, each condition was credited. The percentages listed in Tables 2 and 3, then represent the portion of the 40 raters with experience under each of the conditions specified.

Table 2. Climatic Experience of the Raters

Climatic Condition	Per Cent
Frigid	32.5%
Temperate	82.5%
Semi-tropical	45.0%
Tropical	40.0%

Table 3. Organizational Experience of the Raters

Organizational Condition	Per Cent
Member of a using unit, but not directly connected with the supply of petroleum products.	62.5%
Member of a using unit, directly connected with the handling of petroleum products.	62.5%
Member of a supply depot or supply point for petroleum products. (Battalion or regiment.)	27.5%
Member of a Quartermaster supply point for division or larger units.	22.5%

It is felt that the percentages listed indicate that an adequate variation in experience was sampled. This would substantiate the assumptions made in the selection of the raters cited in the preceding chapter. The high degree of experience indicated for the temperate zone in Table 2 is to be expected since all of the raters have served in the United States. While this service was in garrison for the most part, it is normal that a portion of it might well have been gained on maneuvers, bivouacs, or other simulated combat exercises in which the method of handling petroleum supplies would have been similar to that in question. The high percentages indicated for the first two types of organizational experience are also to be expected. These two conditions would apply principally to conditions in a using unit, and 77.5 per cent of the raters were members of branches of the service that would normally be in this category. The Quartermaster Corps, the supply agency, contributed 22.5 per cent of the total number of raters. This figure corresponds with the percentage of raters with experience as members of Quartermaster supply points for divisions or larger units. However, an investigation of the individual tabulations reveals that all of the Quartermaster officers did not indicate experience in this area. Some members of other branches had experience in this area in addition to experience as a member of a using unit.

Rank order of the size and shape requirements.--The rank order of the requirements which pertain to the determination of the optimum size and shape for the container are presented in Table 4. The mean preference indexes are presented for each of the requirements. These values were tested statistically, using the New Multiple Range Test, to determine whether or not the differences indicated were significant. This technique was employed because it is a more powerful test for significant differences. It allows every preference to be compared to every other one. It also furnishes the experimenter with higher levels of protection than any other similar method.[1] The one per cent level of significance was used for the test. The results are shown in Table 5.

It can be seen from Table 4 and Table 5 that the ability to be lifted by hand was rated as the most important requirement for the design of the container. Further, the value of the mean preference index is significantly better than that of any of the other requirements. The requirement of second importance concerns the ability to satisfy the volume requirements of the using unit with a minimum of handling. Again the difference indicated is significant. The next two requirements in the order of importance, the ability to be transported in a 2 1/2-ton truck with a mini-

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[1] _Ibid_., p. 7.

Table 4. Order of Preference for Size and Shape Requirements

Requirement	Mean Preference Index
A. Ability to be lifted manually.	0.883
B. Ability to satisfy volume requirements of the using unit with a minimum amount of handling.	0.732
C. Ability to be transported in a 2 1/2-ton truck with a minimum waste of space.	0.592
D. Ability to be moved by hand other than by lifting.	0.525
E. Ability to be handled by mechanical equipment as a unit load.	0.375
F. Ability to minimize voids in storage and during transportation.	0.283
G. Ability to be stored in heights of six feet or more.	0.079

Table 5. Results of Statistical Analysis of the Size and Shape Requirements Showing Significance of the Difference in Mean Preference Indexes

Letter Designation (Table 4)	A	B	C	D	E	F	G
Mean Preference Index	0.883	0.732	0.592	0.525	0.375	0.283	0.079

Note: Underlining indicates that there is no significant difference between the mean preference indexes under which the line appears.

mum waste of space and the ability to be moved by hand other than by lifting, are not significantly different than one another, but the former is more important than any listed below it. A similar result is seen for the ability to be moved by hand other than by lifting and the ability to be handled by mechanical equipment as a unit load. The same result is obtained for the next two requirements. However, the ability to be stored in heights of six feet or more is the requirement that is rated least important, and it is significantly less than any other.

<u>Rank order of material requirements</u>.--The rank order of the requirements pertaining to the selection of the best material from which to fabricate the container is presented in Table 6. It may be seen that the ability to withstand outside storage conditions was rated significantly more important than any other requirement. There was no significant difference between the ability to withstand contact with rough surfaces and the ability to withstand sudden stresses, but both were rated higher than those listed below. The ability to be grounded against static electricity was rated of next importance. The ability to be camouflaged was higher than the ability to be collapsed when empty, although the difference was slight and was not found to be significant.

<u>Results of other computations</u>.--Tabulations were summed and mean preference indexes were computed at the eighteenth

Table 6. Order of Preference for Material Requirements

Requirement	Mean Preference Index
A. Ability to withstand outside storage conditions.	0.930
B. Ability to withstand contact with rough surfaces during handling.	0.715
C. Ability to withstand sudden stresses during handling.	0.715
D. Ability to be grounded against static electricity.	0.345
E. Ability to be camouflaged.	0.165
F. Ability to be collapsed when transported empty.	0.130

Table 7. Results of Statistical Analysis of Materials Requirements Showing the Significance of the Differences in Mean Preference Indexes

Letter Designation (Table 6)	A	B	C	D	E	F
Mean Preference Index	0.930	0.715	0.715	0.345	0.165	0.130

Note: Underlining indicates that there is no significant difference between the mean preference indexes under which the line appears.

questionnaire. The relative positions of the requirements were observed. No change of these positions was observed during the tabulation of the remainder of the questionnaires, see Appendix D. Repeat pairs were checked throughout, and no indication of inconsistency in ratings was noted. No errors due to order of presentation were observed.

A tabulation of the relative importance of the various requirements was made for the Quartermaster Corps officers alone and was compared to the ratings of members of all the other branches, see Appendix F. There were no differences indicated in the order of ranking for the two groups with respect to the materials requirements. There was one difference in the ranking of the size and shape requirements. The relative positions of the ability to satisfy the volume requirements of the using unit with a minimum of handling and the ability to be moved by hand other than by lifting were reversed. The Quartermaster Corps personnel gave higher importance to the latter requirement while the other raters normally members of using units, rated the former as being more important.

Discussion of Results

General.--The number of questionnaires is deemed an adequate sample. No method of proving the degree of adequacy is readily available other than by observing the trends of the results throughout the tabulation period as was done. Since no changes were observed with respect to the relative positions of the requirements, it seems safe to assume that these relationships had already approximated the true values. There might have been a possibility of this assumption being erroneous had the results of the experience tabulations indicated that a limited set of backgrounds had been sampled. However, this was not the case. As previously stated, it is felt that the backgrounds represented by this group of 40 raters closely approximates that expected for the Army as a whole.

The checks that were made on the accuracy and consistency of the ratings revealed that the ratings should be reliable indications of the opinions of the raters. It would also seem that each rater was conscientious in accomplishing the rating. As previously mentioned, it is possible that the rater's ability to reflect on previous ratings had an effect on the evidence substantiating these conclusions. The rater might have made his selection as he would for a ranking method, and then completed the form presented with this overall decision in mind. However, the effects of ratings made in this manner would not be detrimental to the results shown in Tables 4 and 6.

<u>Size and shape requirements</u>.--The relative importance of the requirements has been presented in Table 4 and Table 5, and the significance of the results has been discussed. In view of the restrictions placed on the use of handling equipment in a combat zone, it is no surprise that the ability to be

lifted was rated as being most important. The number of times lifting is required for each of the present containers during the supply operation was cited in Chapter II. In fact, it is expected that the great demand for manual handling was the reason for the development of the five gallon can during World War II. However, one criticism of the five gallon can that was registered during the Korean police action was that it required a great number of trips to refuel a vehicle in the using unit.[2] This fact may account for the importance placed on the ability to satisfy the volume requirements of the using unit with a minimum of handling. It can be seen that the aims of the two requirements are opposed to one another regarding the optimum size for the container. The satisfaction of one would lead to the selection of a large container. To satisfy the other the container must be small. A possible compromise might require a size small enough to allow lifting, yet large enough to reduce the handling as much as possible.

Although the mean preference index of the requirement concerning the ability to be transported in a 2 1/2-ton truck was greater than that of the ability to be moved by hand other than by lifting, the difference was not statistically significant. This same relationship is found in studying the results of the individual choices shown in the

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[2] U. S. Department of the Army, R and D Technical Progress Report (1954), p. 376.

matrix, Appendix B, however, the study of the comparative ratings of the Quartermaster Corps personnel with the personnel of other branches cited previously in this chapter would indicate that members of using units consider the former requirement to be of greater importance. Since the reverse was true of the ratings of the Quartermaster personnel, it might well be deduced that the amount of handling in the supply point is not being considered by those individuals not in close oontact with the problem. This effect is to be expected, of course, since the basis for the ratings is the experience of the rater. With respect to the design the apparent equality of the importance of these two requirements necessitates consideration being given to both simultaneously in an attempt to arrive at a compromise solution that will reasonably satisfy both.

The importance of the ability to be transported in a 2 1/2-ton truck was significantly greater than the ability to be handled by mechanical equipment as a unit load, whereas the importance of the ability to be moved by hand other than by lifting was not. Further statistical investigation reveals that there is a significant difference in the latter instance at the five per cent level. An investigation of the individual ratings shown in the matrix, Appendix B, reveals an even greater difference between the two requirements. The ability to be moved by hand other than by lifting was chosen as being more important than the ability to be handled by mechanical equipment as a unit load on seventy per cent of the questionnaires. It is felt that the results indicated by the values of the mean preference indexes for the two requirements and by the absence of a significant difference between the indexes are perhaps caused by the effects of ratings where the other requirements are presented as a pair with each of these requirements rather than by their effects on one another. Since they are both consistently rated near the middle of the list, the two mean preference indexes would necessarily tend to be equal. Yet, consideration of how each was rated when the two were considered only with regard to each other indicates that the ability to be moved by hand other than by lifting is the more important requirement.

The ability to be handled by mechanical equipment as a unit load was not rated significantly more important than the ability to minimize voids in storage and during transportation. The individual ratings as indicated in the matrix, Appendix B, also indicate the same effect. This result is not entirely unexpected inasmuch as the aim of the two requirements with respect to the design of the container is to utilize space. The former requirement has other ramifications peculiar to it, but they would not affect this parallel aim.

As indicated in the results, every requirement was compared statistically to every other one for significant differences between the mean preference indexes. In all of the comparisons not previously mentioned this difference was found to be significant at the one per cent level. The effects of this statistical treatment on the design of the container will be seen in the following chapter as the requirements are integrated into the design of the size and shape of the optimum container.

Material requirements.--The ability to withstand outside storage conditions was rated significantly higher than any of the other requirements. It may have been that the statement included so wide a variety of points of important consideration as compared to the number of such points encompassed by the other requirements listed that an error in the construction of the requirements caused the high degree of preference. However, if it assumed that no such error existed, it would appear that the selection of a material that provides resistance to the effects of extreme temperature conditions, contamination of the product, and corrosion is of extreme importance. In view of the evidence offered in Chapters I and II regarding the necessity for using outside storage the latter assumption would appear to be valid. Certainly a container that did not assure that the contents would be usable upon arrival at the destination would not meet the requirements for an optimum design.

The ability to withstand contact with rough surfaces during handling and the ability to withstand sudden stresses during handling were rated to be of equal importance. The mean preference indexes were the same value so there was no significant difference possible. This fact was not considered to be an obstacle in the design of the container, so the continuation of the distribution of the questionnaires was not felt necessary. The two requirements seem to be aiming at similar or closely related goals as far as design factors are concerned; therefore, the results should not present any major problems in the integration portion of the design. An inspection of the individual choices of the more important of the two reveals that each was chosen approximately the same number of times.

The ability to be grounded against static electricity was rated significantly higher than the two requirements ranked below it. The position of the requirement with respect to those rated above it would seem proper since the grounding can be accomplished by exterior means, which do not necessarily have to be an integral part of the container. Its position with respect to the ability to be camouflaged might be justified by the thought that in supply points and in other places where there are groups of containers stored, the camouflage must be applied tothe stack or section rather than to the individual container. It might also be justified by the seriousness of the threat of fire caused by static electricity as compared to the probability of fire or some other method of destruction to the supply being caused by the enemy. The fact that our forces have retained air supremacy during recent periods of hostility might tend to minimize the latter probability in the rater's opinion. Of course, the supply points for petroleum products are generally located far enough to the rear that threat of enemy observation from the ground is rather remote.

There was no significance found between the mean preference index of the ability to be camouflaged and that of the ability to be collapsed when empty. Justification for the relative importance attached to the former requirement has been presented in the preceding paragraph. A probable justification for the latter lies in the fact that the big advantage to being able to collapse the container is the savings realized in freight charges for the return trip on a civilian railroad. There is no such consideration applicable to the situation in question. Of course, collapsing the container would allow a savings in space, but it is recalled from the discussion of the supply procedure in Chapters I and II that issue of petroleum products is based on the number of cans returned. This means that it would be of no value to the using unit to be able to carry more empty containers on a truck than the number of full ones allowable.

The fact that no significant difference existed between the two requirements is substantiated by the evidence shown in the matrix of the rating of the individual pairs. When presented to the raters as a pair, each requirement was chosen as the more important one an equal number of times. Their relationship to one another is not anticipated to be of great importance in the selection of the material for the container as might be the relationship of each to some of the other requirements. Therefore, these requirements should be considered to be of equal importance.

Summary of results.--In several instances it was noted that a statistical analysis of the results revealed no significant difference to exist between requirements adjacent to each other on the rating scale. In each case, an attempt has been made to justify the absence of a distinct separation as to the degree of importance of each with respect to the other. In most cases, the justification seems to be the similarity of the two requirements regarding the aspect of the design that is affected. The only instance where conflict might arise as a result of the equality of the ratings is the relationship between the ability to be moved by hand other than by lifting and the ability to be transported in a 2 1/2-ton truck with a minimum waste of space. As was stated, a compromise solution must be worked out for the satisfaction of these requirements. The other instance of equality that might present a problem in designing the container, the ability to be moved by hand and the ability to be handled by mechanical equipment as a unit load, was found to have a significant difference between the mean preference indexes at the five per cent level.

Even though it would be desirable to find a significant difference between all adjacent requirements on the rating scale, it is not expected that an increase in the size of the sample would yield this result. This assumption is based on the observations that were made during the process of tabulating the questionnaires. No shifts in relative positions on the scale were observed throughout the tabulation of successive groups of questionnaires. A study of the matrices will show that in every case where requirements were rated equally important except one, the choices made from the individual pair also equal for each.

An investigation of the possibility of the sample being biased with respect to climatic and organizational experience was made. Appendix E presents this information for climatic experience. The same order of ranking appeared regardless of the background of the rater except for the relationship of the ability to be transported in a 2 1/2-ton truck to the ability to be moved by hand other than by lifting. The members of branches of the Army that are normally using units rated the former requirement higher than the latter, while the reverse rating was made by members of the

Quartermaster Corps, the supplying branch. In all other rankings the background of the rater had little effect, if any, on the result.

CHAPTER V

DESIGN OF THE CONTAINER

Procedure to be Followed

The results of the questionnaire presented in the preceding chapter will be utilized for selecting the size, shape, and material for the container design. The first task will be to determine the optimum size by comparing various sizes with the list of requirements that pertain to this factor. The relative importance as established by the results of the questionnaires will set limits for the requirements which must be met in the design. In case conflicting results are obtained in the attempt to satisfy all of the requirements, priority is to be given to the requirement rated highest on the questionnaire. However, no requirement should be sacrificed completely in satisfying another simply because the second received a higher rating.

With the optimum size as a basis, the same process may then be repeated for determining the optimum shape. Standard geometric forms will be used as possible choices for this shape since, as a general rule, they are most easily fabricated. Also, the use of standard shapes provides a basis for the later development of some irregular shape that may better satisfy the requirements. With the optimum size and shape as known quantities, the development of specifications for the material that should be used will be possible using the list of the requirements and the results of the questionnaires. The development of these specifications will follow the same process of integration. It is expected that they will be of a general nature, but should provide a basis for a more complete stress analysis to be made that would allow the selection of the actual material or materials that should be used. No attempt will be made in this paper to complete these specifications further than a general statement. It is felt that further analysis would require laboratory and field tests beyond the nature and scope of this research project.

Some consideration must be given to the manner in which the material requirements effect the determination of the optimum size and shape and vice versa. The sets of requirements are not completely separate from one another in that they both concern the same design. They were originally listed separately to assist the rater in systematically analyzing the whole problem. The use of the shorter lists also reduced the length of the questionnaire, which was intended to make the ratings more accurate and consistent. However, a check must be made to insure that none of the requirements have been slighted as a result of having adopted this procedure

Determination of the Optimum Size

Amount of weight one man can lift.--The ability to be lifted manually was rated significantly higher than each of the other requirements. If this requirement is to be satisfied, the amount of weight a man can lift must be determined. This information was presented for an industrial situation in Chapter I. It was stated that the laws of several states set the maximum at 70 pounds. Evidence was found that the Army in many cases extends this maximum to a value in excess of 100 pounds. The results of a search for descriptions of tasks that are to be performed as prescribed in Army manuals are presented in Figure I.[1] Thirty-eight such references were found. In cases where the task described was a team operation, the total weight of the object being lifted was divided by the number of men prescribed for the team or crew. These weights were then used to compile the histogram. The bulk of the job descriptions that are represented are found in procedures of constructing the standard prefabricated bridges used by the Army. The nature of the work during this construction is felt to be closely

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[1]Data for compilation of the histogram is found in:

The Engineer School, Military Bridging, ROTC ST 35-7 (Fort Belvoir, Virginia, 1954), pp. 96,98,100,190-196,266.

________, Roads and Airfields, St 5-250-1 (Fort Belvoir, Virginia, 1951), p. 549.

U. S. Department of the Army, Browning Machine Gun, FM 23-65, Caliber .50, HB, M2 (Washington, 1944), p. 69.

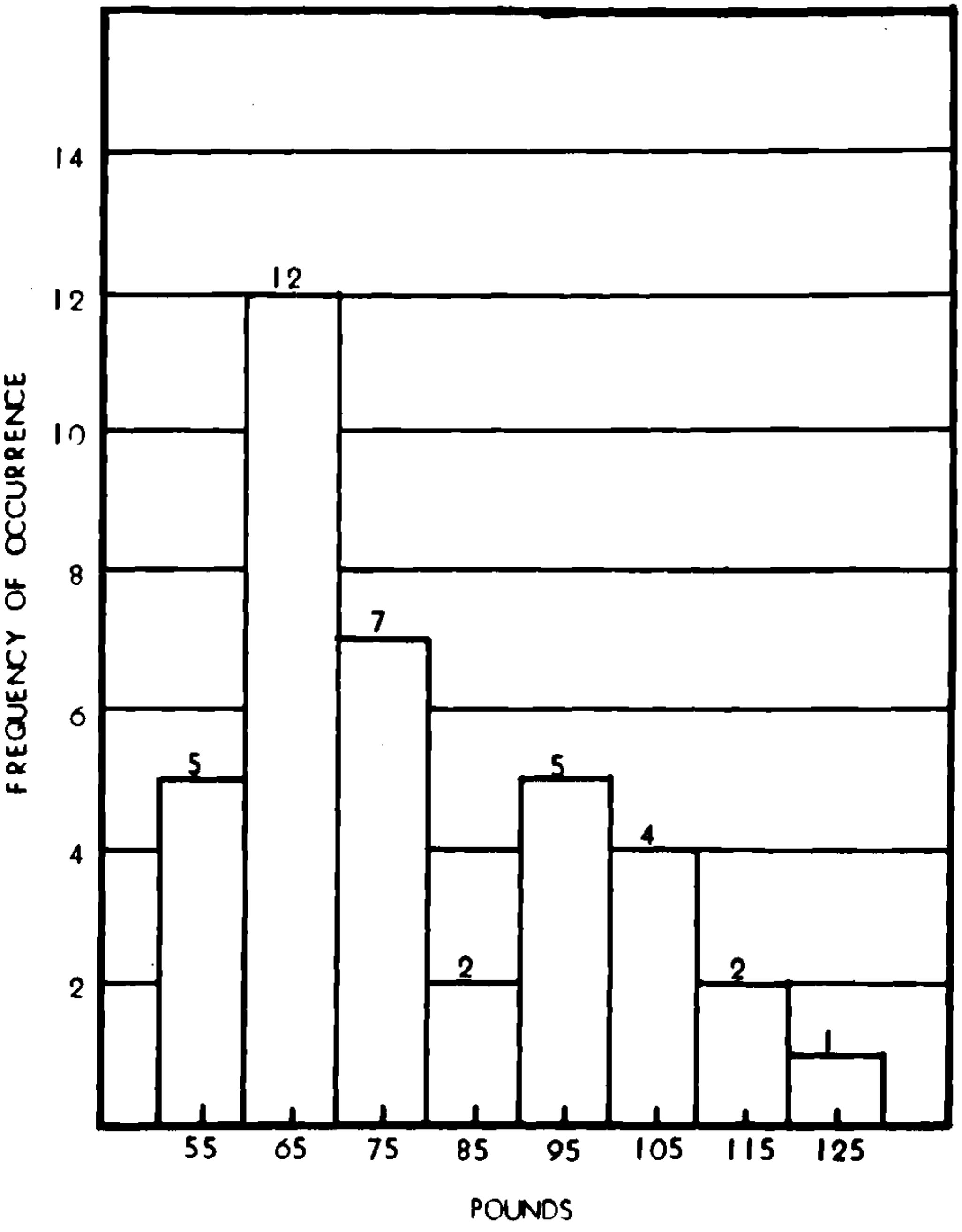

Figure 1. Specified Weights for One-Man Carry Operations in the U. S. Army.

The above data were compiled from a study of prescribed operations described in U. S. Army Field Manuals. Only cases in which the weight to be lifted was 50 pounds or more are included.

similar to that required in moving and lifting petroleum containers in the areas being considered in the problem. That is, when horizontal movement is employed, the distance is held to a minimum, and when vertical movement is necessary for heavy items, it consists of simply raising that item several feet rather than being a combination of the two types of movement. Also, neither type of work is prescribed for long, continuous operations.

It may be seen that in one case, the placing of rocking rollers for launching the Class 60 Panel Bridge, a weight of nearly 130 pounds must be lifted by one man. However, the mode of the histogram is seen to lie between 60 and 70 pounds per man. This figure would seem to substantiate the industrial maximum cited. The conclusion drawn from the evidence is that while it is desirable that a man lift no more than 70 pounds during normal periods of work, he may, under combat conditions, be required to lift weights of 100 to 120 pounds if the situation demands it. If the procedures for lifting that were presented in Chapter I are followed, a man could lift a weight within the latter range safely, provided the lifting is not required for a sustained period of time.

Methods of lifting.--Another point for consideration is the number of ways lifting may be accomplished. The usual way is to lift the entire weight at one time, in which case the effort required is equal to the weight of the object being lifted. This effort is intended to mean the maximum effort required of the person doing the lifting at any one time, and does not refer to the work required to lift the object a specified distrance. It may be possible to accomplish the same amount of work, yet reduce the amount of effort required at any one time. For instance, if the dimensions of the object permit, one side of the object may be lifted at a time. In employing this method, the first side is lifted and placed on a support, such as the dispensing rack in the motor pool of a using unit. This act reduces the maximum effort required at any one time to one-half the weight of the object. Then the other side is lifted to the same elevation, and the object is slid onto the support. The maximum effort required for this stage is variable and could attain a value equal to the weight of the object if the center of gravity of the object were directly above the point of contact for the lower side of the object with the ground. In all other cases, however, this effort would be less than the weight of the object and would vary with the length of the object and the height it is to be raised. For a constant height, the effort would be less as the length of the object is increased.

Even though the use of the second method of lifting, above, does result in a reduction of effort required at any one time in a large majority of cases, the maximum amount of effort may still be equal to that required if the object were lifted at one time. Therefore, no increase in the maximum limit for the weight of the container above that previously stated should be contemplated as a result of methods of handling. It would be advisable to recommend the use of the latter method in any case where its use is permitted by the relationship between the physical size of the container and the height it is to be raised.

Number of men present to lift.--A third point for consideration in the determination of the maximum size for lifting is the number of men that are to do the work. It was stated in Chapters I and II that this number is variable with the type of organization, the situation, and the time of day. Normally there is more than one man available in the supply point and in the using unit. However, since there are situations in which the driver of the vehicle must do all of the handling, the design of the container must allow for this condition. It is contemplated that no increase in size above that previously determined is possible as a result of consideration of this factor.

Volume of gasoline that can be lifted.--The maximum volume of gasoline that can be lifted may be computed after the maximum weight that may lifted is determined. This computation also requires the value of the specific gravity of gasoline and the weight of the container to be known. The value used for the maximum weight that may be lifted can vary from 110 to 120 pounds. The specific gravity of gasoline is 0.69,[2] and the weight of the container will vary with the size. From these values the weight of 80 octane gasoline is computed to be 5.66 pounds per gallon. This figure may be checked against value cited in Chapter I for the weight of the 55-gallon drum when filled, approximately 400 pounds.

The container weight is estimated by assuming that the existing containers weigh a fixed percentage of the total weight when filled. This value for the 55-gallon drum is 23.1 per cent. For the five gallon can the value is 25.5 per cent.[3] Using an average of the two values, 24.3 per cent, for computing the estimated weight of a 110-pound container, the result obtained is 26.5 pounds. It is realized that the method used in these computations is not an absolutely accurate measure, but it is felt that it does provide an estimate that will fit the intended purpose. It is also realized that when the selection of the material for the container is made, every attempt will be made to lighten the container weight as compared to the weights of existing containers. At that time more accurate computations may be made, and alterations of the values here determined may be possible.

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[2]U. S. Department of the Army, Engineer's Reference and Logistic Data, FM 5-35 (Washington 1952), p. 502.

[3]Weight of the empty drum, 94 pounds, divided by the weight of the filled drum, 406 pounds, equals 23.1 per cent. Weight of the empty five gallon can, 10 pounds, divided by the weight of the can when filled, 37.8 pounds, equals 25.5 per cent.

Further computations reveal that if a 15-gallon container were used, the total weight of the gasoline and the container would be approximately 110 pounds (15 gallons multiplied by 5.66 pounds per gallon plus container weight, 24 pounds). The size of the container might vary to a slight degree in either direction from this value and still not be out of the range established for the maximum weight that may be lifted. There should be no reason to alter the size with respect to the volume of gasoline, however, since it is a multiple of five, which should be of assistance to inventorying.

Volume requirements of the using units.--The requirement that was rated to be of second importance in the design of the container was the ability to satisfy the volume requirements of the using unit with a minimum of handling. The two most common types of combat units in the theater of operations are the Infantry Division and the Armored Division. The vehicles found in these units were used as a basis for determining the volume requirements for using units. Tables 8 and 9 summarize the data that were obtained. It may be observed that two sizes of fuel tanks are prevalent for vehicles, the 15-gallon tank on the 1/4-ton truck and the 50-gallon tank on the 2 1/2-ton truck. The fuel capacities of the tanks found in the Armored Division are several times larger than those for the trucks.

Table 8. Wheeled Vehicles Organic to the Infantry and the Armored Divisions

Type of Vehicle	Fuel** Capacity (Gallons)	Distribution* Infantry Division	Distribution* Armored Division
Truck, 1/4-ton, 4x4	15	46.7%	45.7%
Truck, 3/4-ton, 4x4	30	15.0%	11.1%
Truck, 2 1/2-ton, 6x6	50	38.3%	43.2%

Note: The percentages listed refer to the portion of the total vehicular transportation that is represented by each type vehicle.

Table 9. Tracked Vehicles Organic to the Armored Division

Type of Vehicle	Fuel Capacity** (Gallons)	Number Organic to Armored Division*
Tank, light, gun, M24	110	16.1%
Tank, medium, gun, m4A3	168	60.0%
Tank, medium, howitzer	191	4.8%
Tank, heavy, gun, M45	233	19.1%

Note: The percentages listed refer to the portion of the total tracked transportation that is represented by each type of tank.

*The Engineer School, Organization of Engineer Units, ROTC ST 35-1 (Washington 1954), pp.167, 169.

**U. S. Department of the Army, Military Vehicles, TM 9-2800-1 (Washington 1953), pp. 111-119, 122, 230.

In order to absolutely minimize the handling in refuelling the trucks and tanks listed, an extremely large container would be warranted. However, if the restrictions placed on the volume of the container by the previous requirement are considered, more than one full container will be necessary for refuelling all vehicles except the truck, 1/4-ton, 4x4. Assuming that only one container is to be used, the minimum amount of handling cannot be achieved for all vehicles, but the amount of handling necessary will be less than afforded by using the existing containers. It would also be well to note that the vehicles are refuelled at the beginning of each day, which does not necessarily mean that their tanks are empty. If this is the case, the amount of handling might be less than would be indicated by considering the volume of one container against the total vehicle tank capacity of the unit.

The refuelling of the tanks in the armored division presents an entirely different problem since the quantity required is so much in excess of truck requirements. Also the refuelling operation in this division is not a manual operation under normal conditions. The optimum container that is designed cannot be expected to meet every situation that might arise. It is intended to satisfy the requirements of the bulk of the normal situations; however, it is felt that inasmuch as infantry divisions are normally employed in ratio of three to one with armored divisions, reducing the handling necessary to refuel trucks is sufficient reason for feeling that the proposed design may be better than the one now being used.

A compromise solution for the satisfaction of these two requirements would undoubtedly offer two or more sizes of containers for dispensing petroleum products under field conditions. The smaller, 15 gallons, would be used for light vehicles where mechanical handling equipment is not available. The larger would be used where handling equipment is available to minimize the manual work necessary.

Transportation in a 2 1/2-ton truck.--The ability to be transported in a 2 1/2-ton truck was rated of next importance although the values of the mean preference indexes for this requirement and for the ability to be moved manually other than by lifting were not found to be significantly different by the statistical analysis that was made. As previously stated, the procedure in this instance will be to determine the size that will best satisfy each requirement separately. Then by a process of integration, the compromise solution may be decided upon.

Justification of the 2 1/2-ton truck as the choice of the mode of transportation for petroleum products is offered by the statement in Chapter I that this vehicle is the normal one used in hauling these supplies. It may be seen in Table 8 that the 1/4-ton truck and the 2 1/2-ton truck account for approximately 80 per cent of the transportation of the infantry and the armored divisions. The 1/4-ton truck is essentially a personnel carrier, while the 2 1/2-ton truck is the principal cargo carrier for these units.

The dimensions of the body of the 2 1/2-ton truck are: 147 inches long, 80 inches wide, and the loading height is 43.5 inches. The resulting loading volume is 296.6 cubic feet. The container should be designed to minimize the waste of space in filling this volume. This result may be obtained by designing the outside dimensions of the container so that they will be equal increments of the inside dimensions of the truck body. Of course, an allowance must be made for the slight bulging of the sides of the containers when filled as well as for handling room for fitting the containers into the space that exists.

The discussion in the preceding paragraph assumes that the total loading volume will be used. If the payload capacity of the vehicle is used as a limit for the weight the vehicle may carry, it will be seen that less than half of this volume is used when the weight limit is reached. The off-highway payload for the 2 1/2-ton truck is 5,350 pounds.[4] The container weight must then be deducted and is computed by using the percentage to total weight value previously estimated, 24.3 per cent. The remaining weight capacity may be used for gasoline, and further computations show that 670 gallons of 80 octane gasoline in individual containers will be the maximum quantity that may be hauled without exceeding

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[4]*Ibid.*, p. 230.

the payload of the vehicle. On the other hand, if the entire loading volume were filled with this gasoline in individual containers, the load would weigh approximately 12,500 pounds. It might be well to mention that the on-highway payload for the 2 1/2-ton truck is 10,350 pounds,[5] but this value was not used in these computations since travel over rough roads and rough terrain is the usual case in the situation under consideration.

In view of the preceding discussion, it would seem that the demand for space in the 2 1/2-ton truck is not as vital to the design of the container as is consideration for reducing the container weight to a minimum so that a higher percentage of the weight capacity of the vehicle might be utilized for gasoline. The suggested 15-gallon container should be designed to be more efficient in this respect than the five gallon can now being used. The proper selection of the material for the container would help make this increase in efficiency possible.

Preliminary recapitulation.--Since the ability to be lifted manually was rated significantly higher than the ability to be moved by hand other than by lifting, the size of the container is limited to 15 gallons as previously determined. The major effect of the latter requirement on the design, then, is expected to be in the determination of the optimum shape, which will be discussed later. Integrating the re-

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[5] Ibid., p. 230.

sults of the effect of this requirement and the ability to be transported in a 2 1/2-ton truck with a minimum waste of space, it can be seen that no indication for the necessity of reducing the size already suggested exists. It might be desirable to increase the size if the percentage of container weight to total weight could be reduced by so doing.

Effects of remaining requirements.--None of the requirements remaining to be considered should serve to reduce the suggested size for the container. The ability to be handled by mechanical equipment as a unit load might tend to limit the overall size of groups of containers if pallets are to be used. However, it is expected that this limitation will be determined more by the requirement that the container be transported in a 2 1/2-ton truck, and that the pallets used will be designed to fit inside the body of this vehicle. The ability to minimize voids in storage and during transportation pertains to the determination of the optimum shape rather than to the size determination; therefore, will not effect the size suggested. The ability to be stored in heights of six feet or more was rated as being relatively unimportant. The possibility of this situation arising is not eliminated, but it would seem that its occurrance is not of sufficient frequency to warrant a reduction in the size.

Optimum size for container.--In summarization of the size determination, the following statements are made. The maximum size is a 15-gallon container for 80 octane gasoline.

Although the use of this size container will not minimize the handling in satisfying the volume requirements of the using unit, there will be a reduction in the handling as compared to existing methods. Further economy of effort would be possible by the additional use of a larger container where the methods available for handling permit the use of devices to gain mechanical advantage in raising the container to various heights as required. It is not possible to complete the dimensions of the container until an optimum shape is determined, but it is expected that they will meet the criteria of being equal increments of the inside dimension of the body of the 2 1/2-ton truck and of being within a height limitation that will allow the center of gravity of the load to remain below the top of the truck sidewall. The last stipulation is made to reduce the tendency of containers to topple from the truck during transit if a partial truckload is hauled. This is an important factor when the load is being transported cross country as is done frequently in the combat zone.

Determination of the Optimum Shape

Shapes for consideration.--Five regular, geometric shapes will be considered in the design. They are: the cube, the sphere, the cylinder, the pyramid, and the prism. The handling characteristics of these shapes will be studied with respect to the degree to which each is able to satisfy the container requirements. For instance, the shape alone should not greatly affect the ability to lift the 15-gallon container manually. For this container each of the shapes should meet the demands of this requirement adequately. It is also assumed that each of the shapes would enable the container to meet the requirements of being able to satisfy the volume requirements of the using unit with a minimum of handling. These requirements pertain chiefly to the determination of the optimum size rather than to the determination of the shape.

Considering hauling efficiency.--The ability to be transported in a 2 1/2-ton truck with a minimum of wasted space and the ability to be moved manually other than by lifting must again be discussed together. The immediate observation is that the two requirements are going to oppose each other in their effects on the optimum design. In meeting the former requirement, it is desirable to place the containers in a manner that minimizes the empty space between the containers. The cube will best satisfy this nesting ability. No wasted space should remain if the cube were used. The prism would meet the requirement adequately, but there would be an increased amount of wasted space if the cylinder were used. The pyramid and the sphere would not satisfy the requirement adequately. However, the discussion and computations that were offered when consideration to this requirement was given regarding the determination of the optimum size revealed that some space could be spared without loss to the efficient utilization of transportation.

<u>Methods of moving the container manually</u>.--Several methods of moving containers other than by lifting and carrying were mentioned in Chapters I and II. Rolling was among those mentioned. Sliding the container is possible. Dropping was cited as a possibility providing a tire was used to cushion the shock. When vertical movement is necessary, the use of ramps was recommended. All of these possibilities might well be utilized in the container design, even though the container size that has been suggested allows lifting. If it were possible to reduce the effort required to move the container except for the times that lifting is required, the handling would more closely simulate the conditions described for the construction of the prefabricated bridges. This simulation is to be desired since the bases for determination of the maximum weight that could be lifted by one man were the bridge construction methods.

In determining which shape best satisfies the requirement, certain facts derived from laws of physics must be considered. One is that horizontal movement requires the least amount of effort. Another is that the use of the inclined plane requires less effort at anyone instant than does lifting when vertical movement is necessary. The container may be rolled or slid horizontally. It may also be rolled or slid up an inclined plane. Rolling friction, however, presents much less resistance to movement than does sliding friction. The coefficient of rolling friction is usually in the range of 0.001,[6] whereas that for sliding friction may be as great as the range of 0.1. Therefore, the shapes that can be rolled, the sphere and the cylinder, would best meet the needs of this requirement. The cylinder is probably the easiest to control as to the direction of movement, and it is certainly the most versatile for allowing ropes and other expedients to be applied to reduce the amount of effort required to roll it.

If any of the other shapes were used, sliding or perhaps toppling could be employed as methods of moving. Both means would cause excessive wear or damage to the container material and would probably demand an increase in the thickness of the material as well as strengthening of the seam construction, which would in turn increase the container weight. Any increase in this weight is undesirable; however, in the event one of the shapes satisfied the other requirements more completely, the following information is offered. The cube affords more surface area perpendicular to the direction of movement and would be the easiest to push or to pull unless expedients were used. Toppling should be avoided since excessive stresses would result which would reduce the life of the container considerably.

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[6]C. E. Mendenhall et al., College Physics (Boston 1944), p. 65.

Choice of compromise shape.--As anticipated, the satisfaction of the two requirements has resulted in a choice between two different shapes. The best shape for minimizing the wasted space in the 2 1/2-ton truck is the cube. The best shape for movement by hand other than by lifting is the cylinder. The lack of necessity for entirely filling the loading space of the truck, therefore, becomes an important factor in making a compromise decision as to the one shape that best fits both requirements. If it is not necessary to use all of the loading space, an increase in the height of the container might affect a reduction in the amount of floor area to be used. Since some floor area may be allowed to become wasted space, then the cylinder may be used without sacrificing the efficiency of the vehicle in hauling petroleum products.

If sliding or toppling is used as a method of movement of the cube the container must be designed to withstand greater stresses, which would result in a heavier container than would be necessary if a cylinder were used. The increase in weight of the container would reduce the efficiency of the cube as a container in that more of the payload of the 2 1/2-ton truck would be required in carrying containers rather than for carrying gasoline.

Methods of unit loading.--In comparing the ability to be moved by hand other than by lifting with the ability to be handled by mechanical equipment as a unit load, it should be recalled that the investigation of the choices made when the two requirements were presented as a pair revealed that the former was chosen as being more important on 70 per cent of the questionnaires. This result may be attributable to the lack of handling equipment in the organizations at present. It could also be that the raters realize the inability of standard materials handling equipment to operate over rough terrain, which might cause them to feel that consideration for this possibility is relatively unimportant. The raters might also have felt that even if mechanical equipment is designed to operate over rough terrain, the small amount of handling done in the using unit might not warrant such equipment being made available in these areas. All of these thoughts would be attempts at a practical solution on the rater's part and the fact that the use of mechanical equipment was not given a high degree of importance should in no way be construed to indicate that the raters do not realize the amount of effort that would be saved by its use.

The present method of handling petroleum products in the areas under consideration utilizes the A-frame kit mounted on the 2 1/2-ton truck as cited previously. Three drums may be moved at one time by using the three-pronged chain slings. Actually it is possible to move six drums at a time using this equipment if the situation demands. The use of this practice was cited by personnel with experience in operating the equipment. It must be realized that a degree of safety is sacrificed when the latter method is employed. A pallet might be used for handling the five gallon cans with this equipment, although at present these containers are loaded onto the truck manually. Crawler-type cranes are used in a similar manner in the rear areas and provide more handling flexibility than the A-frame kit. These cranes might be employed in the forward areas except for their lack of mobility in moving from place to place. Mobile cranes do not have this disadvantage to as great an extent, but their overall size does often limit their employment in the theater of operations. The cost of the equipment is another consideration. It is too large to permit assignment of the equipment to an area where it might easily fall into enemy hands.

The possibility of using the fork truck together with the stage of development of the rough terrain fork truck were discussed in Chapter I. The maximum load to be handled over rough terrain is not determined, but it is assumed that the capacities would closely correspond to those of the industrial fork trucks being manufactured presently. There might be a limitation on stacking height while travelling because of the possibility of overturning, but the aims of the design are to overcome this difficulty.

The shape for the container that would best satisfy the needs of this requirement will depend, to some extent, on the type of mechanical handling equipment that is to be used. If pallets are to be used, the best shape would be similar to that determined for efficient transportation in the 2 1/2-ton truck, that is, the cube. If the chain slings are used without pallets, the handling requirements could be satisfied adequately by the cylinder as well as the cube. The determining factor in the design in the latter instance would be the provision for a lip or rolling hoop on the container, which would allow the attachment of the slings. The sphere does not lend itself to adequate utilization of space in a unit load. The pyramid and the prism would be better shapes to use than the sphere, but not as good a choice as the cube.

The compromise choice for the shape that best meets the needs of both requirements, the ability to be moved by hand other than by lifting and the ability to be handled by mechanical equipment as a unit load, would seem to be the cylinder. This shape does allow flexibility of movement at a savings in effort when being moved by hand other than by lifting. It may also be handled in groups as a unit load if the proper appendages are added. It may even be loaded on pallets with no more waste of space than existed when its ability to be transported in a 2 1/2-ton truck was considered. It was shown at that time that the necessity for using all of this space was not of great importance. If the existing method of manually loading the small containers onto the 2 1/2-ton truck in the supply point is continued, the cylinder would certainly prove beneficial as a labor saving device.

<u>Consideration for remaining requirements</u>.--The ability to be handled by mechanical equipment as a unit load and the ability to minimize voids in storage and during transportation have ultimately the same aim concerning the selection of the shape for the container design. Both requirements demand that as little wasted space be allowed to exist as possible. The compromise choice in this case would then be the cube. Storing and hauling containers is most efficiently accomplished when this shape is used.

The ability to be stacked in heights of more than six feet was rated as the least important requirement, but it is possible that such a necessity might arise. In any stacking operation cube-shaped containers will be safer and easier to handle than any other shape. Greater stability for the stack is afforded and no side supports are necessary. If the cylinder is stored on its base in an upright position, the same advantages exist, but storing on the side has been used because possible contamination of the product by water collecting on the container top must be considered.[7]

<u>Design of the container</u>.--One aspect of the container design that has been mentioned in connection with the satisfaction of several requirements is the fact that the container weight must be minimized. The minimum container weight

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[7] Quartermaster School, <u>U. S. A. R. Schools Instructor's Guide, Third Year Basic</u>, p. II-5.I.

should be obtained for any given material and shape when the surface area is a minimum. The dimensions for the container may then be computed for the 15-gallon cylinder by using standard methods of differential calculus. These computations indicate that the diameter of the cylinder should be 13.5 inches, and the height should be 24.1 inches. However, consideration must be given to the outside dimensions of the container being increments of the inside dimensions of the truck body that hauls them. As previously cited, these dimensions are 147 inches by 80 inches by 43.5 inches. If the diameter of the container is decreased to 12 inches, sixty such containers could be placed as one layer in the 2 1/2-ton truck body. Assuming the same ratio of container weight to total weight as before, this number of containers would overload the truck during cross-country travel by approximately 950 pounds. If, on the other hand, the diameter were increased to 15 inches, 45 such containers could be placed as a layer in the truck body. The truck would still be overloaded by 350 pounds, but it is anticipated that a material will be selected that will permit a reduction in the container weight.

The increase in the diameter would allow a reduction in the container height to 19.75 inches. Therefore, the use of one layer would only require slightly less than one-half of the loading height of the truck body. The extra space would allow a second layer of containers to be hauled if the condition of the road permitted an increase in the payload rating of the vehicle. It is assumed that the 15-inch diameter will also allow the handling clearance during loading that is required as previously cited.

The 15-inch diameter cylinder actually allows a minimum surface area, 7.56% less than that for the 12-inch cylinder, therefore makes the container weight a minimum as far as the design considerations to this point are concerned. It would be chosen as the optimum size at this point in the design pending the changes that might be necessary when the seam design and the closure design are determined. Even though the cylinder was selected consideration might be given to the dimensions of the cube that would allow the minimum surface area as an alternate design. Using the same mathematical computations as for the cylinder, the result would be a cube which has length, height, and width dimensions of 15.19 inches. This container could be loaded in the same fashion as the cylinder with the same fuel capacity resulting. The entire floor area of the body of the truck would not be used, but there would not be sufficient space for the placement of another row of containers across the rear. This row would not be necessary, however, since the payload of the vehicle would already have been exceeded by 350 pounds. The total surface area for this cube is 1490 square inches, which is 207 square inches more than the 1283 square inches of area for the 15-inch diameter cylinder. Assuming that the same thickness of material and the same method of seaming were used in both containers, the cylinder would be 13.9 per cent lighter than the cube which provides another advantage for its use.

Specifications for the Selection of the Material for the Container

Ability to withstand outside storage conditions.--This requirement encompasses prevention of contamination of the product, as previously discussed, which is usually accomplished by several means. Full containers are kept airtight by properly designed closures and seams. Supervision is necessary to minimize carelessness by the handlers in the prevention of outside sources of contamination, such as, dirt, dust, water, rust, gum, or other varieties of petroleum coming in contact with the product. It would seem then that the problem can be solved by selecting a material that is resistent to corrosion, that permits the workability for proper seaming, and that has a coefficient of expansion of approximately equal value to that of the material from which the closure is to be made so that fluctuations in temperature will not cause openings between the closure and the container.

Ability to withstand rough treatment during handling.--Satisfying the next requirements in order of importance, the ability to withstand contact with rough surfaces and the ability to withstand sudden stresses during handling, seems to demand the selection of a material that will take rough treatment. The material must be able to withstand being dropped from heights as great as five feet when filled with a petroleum product. It must also have a high resistence to abrasion or else be flexible enough to minimize the effects of contact with rough surfaces. Consideration for these qualities must include the characteristics of the material at extremely low temperatures.[8] The container seams might well be the critical area for consideration in this respect.

Consideration of the remaining requirements.--The material should have the ability to be grounded against static electricity. Of course, this grounding can be provided by the container or it may be sufficient if a ground is attached externally. The ability to be collapsed when empty is not mandatory, as previously discussed. If it is part of the container design, it should be permitted only when it does not mean sacrificing any of the requirements previously discussed. The requirement concerning the ability to be camouflaged should be considered; however, it should be remembered that camouflage can be accomplished by using garnishing nets, natural vegetation, and other items.

Of course, the economy of the material selection cannot be overlooked. This factor was purposely omitted from

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[8] U. S. Department of the Army, R and D Technical Progress Report (1951), p. 25.

the questionnaire since information necessary for the intelligent determination of economy was not available to the raters. Their experience in making determinations of this sort was also questionable. It is believed that this determination is a problem for the designer.

These requirements are of a general nature and would require further refinement before specifications would be evolved that would allow the selection of materials that would be tested as pilot models. In some instances, laboratory tests are required before the materials can be selected. No attempt has been made in this paper to refine the specifications for reasons previously stated. Rather, it is considered significant that an order of importance has been determined for each requirement that will allow specifications to be made based on the ratings of personnel experienced with handling petroleum products in the field.

CHAPTER VI

CONCLUSIONS

Determination of the optimum size.--The first conclusion is that no one size and shape for the container will allow all of the requirements to be fulfilled completely. Therefore, a compromise of the requirements is necessary. If the relative importance of the requirements is used as a basis for this compromise, the solution for the optimum container size is a 15-gallon container, which weighs approximately 110 pounds. This size is limited by the importance of its being lifted by one man. There is considerable improvement in handling efficiency over the existing container offered by the adoption of this size even though a larger container would further minimize the handling. All other requirements would be adequately met, depending upon the selection of the optimum shape for the container.

Determination of the optimum shape.--In determining the optimum shape for the container, the cylinder and the cube were the two basic geometric shapes most frequently mentioned as being satisfactory in meeting the requirements. Either of the two may be lifted manually, depending on the size. The same is true of their relative ability to satisfy the volume requirements of the using unit. The cylinder might have a slight advantage in that it may be rolled, which requires less effort than would be required for lifting or sliding the cube. The cube allows less space to be wasted during transportation in the 2 1/2-ton truck, but the necessity for utilization of space in this instance has been shown to be of minor importance. The cylinder may be hauled in the truck with efficient use of space. The cylinder is the easiest shape for manual movement other than lifting and it may be handled by mechanical equipement as a unit load, although the cube has the best characteristics for utilizing space in this respect. The cube also allows a minimum waste of space during storage and during transportation and provides the greatest degree of safety in stacking operations, although the cylinder is practically as safe if stored upright. It is felt that this discussion indicates that the compromise solution allowing the greatest number of more important requirements to be satisfied is a 15-gallon cylinder.

Design of the container.--The dimensions of the container were established by assuming that a minimum surface area would allow the container weight to be minimized. This assumption was made with the qualifying statement that the seam design, closure design and selection of material from which the container is to be made will in all likelihood cause some adjustments to be necessary. However, based on the information presently available a 15-inch diameter cylinder, which has a height dimension of 19.75 inches, was selected. This size would allow the surface area to be minimized with consideration being given to the necessity for the outside dimensions of the container being increments of the inside dimensions of the truck body. In addition, consideration was given to the extra space needed for handling and loading.

It was pointed out that a great number of these containers would have to be handled in refuelling the tanks in the armored division. Construction equipment and other large capacity vehicles would present the same difficulty. It is suggested that a larger container be developed for service where these items are organic equipment. In fact, information has been received recently that the Army's tanks may soon be refuelled by a new system, which employs the use of two 600-gallon tanks is almost 1,000 pounds less than the same amount of fuel in five gallon cans.[1] Preliminary tests have been successful at the time of this writing, and the adoption of the unit seems likely. When put into use, it might also prove advantageous for use in the other cases just mentioned. Until such time as this or a similar unit is adopted, units located in the rear areas of the theater of operations might still find the use of a large container feasible. Prisoner of war and indigenous labor are widely used for manhandling supplies. There is also a greater possibility for the use of ramps and other devices to gain

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[1] "New Tank Refueller Developed," The Army-Navy-Air Force Register, Jan. 28, 1956, p. 10.

mechanical advantage since the units are more permanently settled. There may even be mechanical handling equipment available in many units.

Specifications for material selection.--The statements of the specifications for the material from which the container is to be made were given in general terms in Chapter V. Further refinements to each would have to be made before a material could be selected. As was previously stated, this project is considered to be beyond the scope of this research. It is, however, considered significant that an order of preference has been determined that will allow specifications to be made based on the ratings of personnel experienced with handling petroleum products under field conditions in the Army.

APPENDIX

APPENDIX A

PETROLEUM CONTAINER QUESTIONNAIRE

This questionnaire is part of a graduate research project at Georgia Institute of Technology.

The purpose of this rating form is to determine the importance of certain requirements for the design of a container for petroleum products for field use by the Army. As you will note, these requirements pertain to the handling of the container in the depot supplying the using unit and in the motor pool of the using unit. It is felt that these areas are critical since there is a minimum of handling equipment available.

You have been selected as a rater because of your experience with the supply of petroleum products in one or both of the critical areas under field conditions. On the basis of this experience, you are asked to rate each requirement against the others in the lists. The requirements are listed in pairs in the order in which you should rate them. Consider each pair of requirements separately and select the more important one of that pair.

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Before accomplishing the rating of the requirements on the attached sheet, please answer the following questions concerning the nature of your experience. Indicate your answer by encircling the letter preceding the choice or choices that most accurately describe this experience.

1. In which of the climatic zones listed below was your experience gained?

   a. Frigid
   b. Temperate
   c. Semi-tropical
   d. Tropical

2. Under which of the following organization conditions was your experience gained?

   a. A member of a using unit, but not directly connected with POL handling.
   b. A member of a using unit and directly connected with handling POL supplies.
   c. A member of a supply depot or supply point for POL. (Battalion or Regiment).
   d. A member of a QM supply point for division or larger units.

PART I. SIZE AND SHAPE REQUIREMENTS

1. Ability to be moved by hand other than by lifting.

2. Ability to be lifted manually.

3. Ability to be handled by mechanical equipment as a unit load, i.e. combined so that more than one container may be handled at the same time.

4. Ability to be stored in heights of six feet or more.

5. Ability to be transported in a 2 1/2-ton truck with a minimum waste of space.

6. Ability to satisfy volume requirements of using unit with a minimum handling. (Using unit can fill vehicles with a minimum wasted effort in handling containers.)

7. Ability to minimize voids in storage during transportation.

COMPARISON RATINGS: The following pairs of numbers refer to the numbered requirements listed above. Which requirement of each of the pairs listed do you consider to be the more important one? Encircle the number which indicates your choice below.

5 or 7	2 or 6	3 or 7	2 or 5	7 or 1	3 or 6
6 or 7	1 or 5	6 or 4	1 or 2	6 or 1	5 or 6
3 or 4	5 or 3	2 or 4	7 or 2	4 or 2	7 or 4
4 or 1	3 or 1	2 or 3	4 or 5	3 or 2	1 or 3

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PART II. MATERIAL REQUIREMENTS

1. Ability to withstand outside storage conditions.
   a. Severe extremes of heat and cold.
   b. Contamination of contents by dirt, water, etc.
   c. Ability to resist corrosion (especially on the interior surface).

2. Ability to be camouflaged.

3. Ability to be grounded against static electricity.

4. Ability to be collapsed when being transported empty.

5. Ability to withstand sudden stresses during handling. (being dropped, etc.)

6. Ability to withstand contact with rough surfaces during moving or handling.

COMPARISON RATINGS: The following pairs of numbers refer to the numbered requirements listed above. Which requirement of each of the pairs listed do you consider to be the more important one? Encircle the number which indicates your choice below.

2 or 3	1 or 2	3 or 1	5 or 1	3 or 6	2 or 1
4 or 1	4 or 5	6 or 2	4 or 6	5 or 6	4 or 2
5 or 3	6 or 4	2 or 5	6 or 1	3 or 4	1 or 4

APPENDIX B

Mean Preference Indexes of Individual Requirement Choices on the Paired-Comparison Questionnaire Size and Shape Requirements

Requirements*	A	B	C	D	E	F	G
A	-----	0.225	0.150	0.250	0.075	0.050	0.000
B	0.775	-----	0.250	0.150	0.075	0.025	0.100
C	0.850	0.750	-----	0.400	0.250	0.175	0.025
D	0.750	0.850	0.600	-----	0.300	0.200	0.150
E	0.925	0.925	0.750	0.700	-----	0.375	0.075
F	1.000	0.975	0.825	0.800	0.625	-----	0.125
G	1.000	0.900	0.975	0.850	0.925	0.875	-----
Total	5.300	4.625	3.550	3.150	2.250	1.700	0.475
Mean Index	0.883	0.771	0.592	0.525	0.375	0.293	0.079

* Letters designating requirements are used as follows:

A - Ability to be lifted manually.
B - Ability to satisfy the volume requirements of the using unit with a minimum handling.
C - Ability to be transported in a 2 1/2-ton truck with a minimum waste of space.
D - Ability to be moved by hand other than by lifting.
E - Ability to handled by mechanical equipment as a unit load.
F - Ability to minimize voids during storage and transportation.
G - Ability to be stored in heights of six feet or more.

APPENDIX C

Mean Preference Indexes of Individual Requirement Choices on the Paired-Comparison Questionnaire Material Requirements

Requirement*	A	B	C	D	E	F
A	-----	0.000	0.025	0.000	0.075	0.250
B	1.000	-----	0.700	0.475	1.000	1.000
C	0.975	0.300	-----	0.175	0.925	0.900
D	1.000	0.525	0.825	-----	1.000	1.000
E	0.925	0.000	0.075	0.000	-----	0.425
F	0.750	0.000	0.100	0.000	0.575	-----
Total	4.650	0.825	1.725	0.650	3.575	3.575
Mean Index	0.930	0.165	0.345	0.130	0.715	0.715

* Letters designating requirements are used as follows:

A - Ability to withstand outside storage conditions.
B - Ability to be camouflaged.
C - Ability to be grounded against static electricity.
D - Ability to be collapsed when being transported empty.
E - Ability to withstand sudden stresses during handling.
F - Ability to withstand contact with rough surfaces during moving or handling.

APPENDIX D

Relative Ranking of Requirements After 18 and After 40 Questionnaires

Requirement*	Position After 18 Questionnaires	Position After 40 Questionnaires
Size and Shape Requirements:		
A	1	1
B	2	2
C	3	3
D	4	4
E	5	5
F	6	6
G	7	7
Material Requirements:		
A	1	1
B	2	2
C	3	3
D	4	4
E	5	5
F	6	6

*Letters designating requirements are used as follows:

Size and Shape Requirements.

A - Ability to be lifted manually.

B - Ability to satisfy volume requirements of the using unit with a minimum of handling.

C - Ability to be transported in a 2 1/2-ton truck with a minimum waste of space.

D - Ability to be moved by hand other than by lifting.

E - Ability to be handled by mechanical equipment as a unit load.

F - Ability to minimize voids during storage and transportation.

G - Ability to be stored in heights of six feet or more.

Material Requirements.

A - Ability to withstand outside storage conditions.

B - Ability to withstand sudden stresses during handling.

C - Ability to withstand contact with rough surfaces during moving or handling.

D - Ability to be grounded against static electricity.

E - Ability to be camouflaged.

F - Ability to be collapsed when being transported empty.

APPENDIX E

Relative Ranking of Requirements Under Various Climatic Experiences

Requirement*	Climatic Condition			
	Frigid	Temperate	Semi-Tropical	Tropical
Size and Shape Requirements:				
A	1	1	1	1
B	2	2	2	2
C	3	3	3	3
D	4	4	4	4
E	5	5	5	5
F	6	6	6	6
G	7	7	7	7
Material Requirement:				
A	1	1	1	1
B	2	2	2	2
C	3	3	3	3
D	4	4	4	4
E	5	5	5	5
F	6	6	6	6

*Letters designate requirements as before, see Appendix D.

APPENDIX F

Relative Ranking of Requirements
Quartermaster Personnel vs. Others

Requirement*	Ranking and Mean Preference Index	
	Quartermaster	All Others
Size and Shape Requirements:		
A	(1) 0.900	(1) 0.860
B	(2) 0.767	(2) 0.772
C	(4) 0.524	(3) 0.631
D	(3) 0.716	(4) 0.461
E	(5) 0.299	(5) 0.383
F	(6) 0.273	(6) 0.287
G	(7) 0.033	(7) 0.094
Material Requirements:		
A	(1) 0.945	(1) 0.930
B	(3) 0.700	(2) 0.748
C	(2) 0.800	(3) 0.680
D	(4) 0.280	(4) 0.352
E	(5) 0.260	(5) 0.160
F	(6) 0.100	(6) 0.106

*Letters designate requirements as before, see Appendix D.

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